THE SANITATION OF BUILDINGS

BY

E. THOMAS SWINSON

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PREFACE

THE 'sanitation of buildings' is a subject of so wide a scope that it is impracticable, in a volume of limited size, to deal in a sufficiently comprehensive manner with all the requisite details. In the circumstances it has been deemed advisable to omit a detailed consideration of water-supply, lighting, warming, and ventilation, and concentrate on site and environmental conditions, sanitary construction and exclusion of dampness, means for the reception, removal, and disposal of waste matters, and special hygienic requirements.

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SITES

IN the selection of a site for habitation the primary essential is 'healthiness', which expression is taken as indicating a state of freedom from conditions inimical to the welfare of persons housed thereon and arising from position, formation, or surroundings. A 'healthy' site, however, may conceivably be of such character that residence is reduced to an inurement to hard and trying conditions, and therefore the possibility of securing an environment providing a reasonable measure of comfort as well as health should not be ignored. Consideration of local phenomena permits of certain guiding principles being laid down in the selection of a healthy habitable site.

Relation of the Soil to Disease

A dry soil, such as primitive rock, may be relatively sterile, whereas a degraded soil—particularly if moist—is a 'living' earth in which micro-organisms abound, the number and nature of these depending upon the soil formation, content, and temperature.

Bacteria are mostly confined to surface soils, but few being found below 3 ft. Prominent forms are (*a*) decomposing and denitrifying bacteria whose activities in soil rich in organic matter are spent in breaking down compounds of ammonia and nitrogen into free nitrogen, carbon dioxide, ammonia, water, and nitrates, and (*b*) aerobic nitrifying bacteria which oxidize the ammonia bodies resulting from the first, or breaking-down process, into nitrites, and then, by a further stage, convert the latter into nitrates. The usefulness of these bacteria can hardly be overstated, as they convert putrescible organic matter into a harmless and inodorous humus, and are thus scavengers and purifiers of the soil. A typical

representation of their work is the purification of sewage by what is known as the bacterial process.

In addition to these beneficial bacteria, some soils afford a harbourage, and in particular instances a propagating ground, for the micro-organisms of specific diseases, it being accepted that 'anthrax, tetanus, malaria, enteric fever, cholera, diarrhoea, and yellow fever are closely concerned with telluric conditions'.[1] Infection of the soil with the bacilli of enteric fever, cholera, and diarrhoea or dysentery is usually brought about by infective matter evacuated by persons suffering from the disease. The bacilli of anthrax and tetanus are imparted from the discharges of diseased animals, and apparently become indigenous in certain soils.

Soil structure and temperature play a significant part in the incidence and mortality of epidemic diarrhoea, the mortality being high on loose porous, and low on rock soils. Organically polluted, damp, aerated soils, when associated with a fairly high temperature, appear to be most favourable to the development of the infective organism and for the summer rise of mortality, the infection presumably being air-borne.

The specific parasite of malaria (which includes various forms of intermittent and remittent fevers) has its habitat in surface water or saturated soil charged with decomposing vegetable organic matter and of a temperature suitable to the breeding of the species of mosquito (*anopheles*) which acts as the host of the parasite and communicates the infection to man. Marshy land covered with rank vegetation and stagnant water pools containing vegetable growth are ideal breeding places.[2] Open cesspits and drainage places with a temperature not under 50° F. also provide a suitable *locus*. According to Ghosh

[1] *Hygiene and Public Health*, p. 166. Whitelegge and Newman.

[2] In towns a breeding place or *locus* for mosquitoes is sometimes established in the most unlooked-for circumstances. On several occasions the author has found the habitat in small ground areas adjoining drain outlets provided and used solely for the discharge of hot water and condensed steam from boilers.

and Das,[1] these insects 'are the sole agents for the spread of malaria and yellow fever. "No mosquitoes, no malaria" is a universally accepted sanitary dogma of to-day'.

Infective organisms may be carried by washings into surface streams, downwards by the subsoil water through the pores of permeable, and faults and fissures in impermeable, soils to springs and wells and thus contaminate supplies of potable water; and to the surface of the soil by insects and ground air, where drying can take place and the infective particles be air-borne as dust or carried by flies and deposited on food, or inhaled direct from the atmosphere into a person's system.

As a general observation, a warm, moist soil having a large proportion of decaying vegetable matter, or polluted with excremental or other putrescible animal matter, and with a temperature above 60° F., favours the vitality and propagation of infective organisms. A cold, wet soil predisposes to diphtheria, catarrhs, rheumatism, phthisis, bronchitis, pneumonia, and other respiratory affections, and generally may be the precursor of disease by lowering the vitality and resisting power of human beings continuously subjected to its influence.

In referring to the effects of moisture it must not be understood that atmospheric humidity in the form of rain is in itself harmful; neither can it be urged that districts having a high mean average rainfall are more unhealthy than places where the average is low. There is, however, evidence that in temperate climates a close relation exists between dampness, both of air and soil, and particular diseases. On tubercular disease Blyth stated:[2] 'The combinations of damp soil, an atmosphere laden with moisture, and variable weather, are the most favourable, and the reverse of these the least favourable, for the dissemination of the malady;' and Whitelegge and Newman suggest[3]

[1] *Hygiene and Public Health*, p. 272. Ghosh and Das.

[2] *A Manual of Public Health*, pp. 450–1. A. Wynter Blyth.

[3] *Hygiene and Public Health*, pp. 166–9. Whitelegge and Newman.

(1) that 'dampness of soil is favourable to phthisis and diphtheria'; (2) that with malaria 'a rise of ground water due to heavy rainfall, or impeded or insufficient outflow, is a common antecedent of severe outbreaks in malarious districts'; (3) that 'enteric fever, cholera, and yellow fever are often endemic, a fact that in itself is strongly suggestive of telluric relations'; (4) that 'dampness of site is favourable to all affections of the respiratory system, including bronchitis and pneumonia'; and (5) that 'in the absence of definite evidence the popular theory that damp and cold soils are conducive to rheumatism and all manner of catarrhs may be provisionally accepted'.

A cursory examination of the available data indicates that excessive soil moisture has a direct bearing not only upon the comfort of a site, but also on its healthiness, and if a proof is needed as to the relationship between a wet soil and a moisture-laden atmosphere and malarious diseases, it is to be found in the classical instance of the fen districts of certain of the English eastern counties, where the elimination of excessive soil-moisture by efficient draining has effaced serious cases of ague and other forms of intermittent fever in districts where previously these were rampant.

Ground or Subsoil Water

Soil moisture is derived from the rainfall—a term including all forms of atmospheric precipitation—and subterranean supplies. The quantity of rainfall absorbed depends upon exposure, the surface gradient, state of openness of the surface pores, and soil texture. Solid rock presents a barrier to free infiltration except by means of faults and interspaces, and hard-baked or consolidated surfaces also impede infiltration. If such surfaces have a steep gradient a large proportion flows away instead of being absorbed. Light open-pored soils, such as sand and cultivated land in a good state of 'tilth', most readily take in the rainfall.

In air-dry soils a small quantity of moisture is usually present in hygroscopic form, i. e. as a thin film held to the soil particles by surface tension. Drained soils may be in a more or less complete state of saturation, the water being held to the surfaces of the soil particles and in the voids or interspaces by surface tension. Undrained and insufficiently drained soils contain ground water subject to percolation if given proper facilities.

The capacity of a soil for water varies with the grading of the particles, their porosity, and the proportion of voids. The optimum is found where the soil is saturated and the interspaces fully charged to the exclusion of air. Of the rainfall absorbed part percolates through and part is retained: of the latter a large percentage is eventually evaporated into the atmosphere. The amount respectively removed by these means is determined by the facilities offered for percolation, the texture and specific heat of the soil, and the condition of the atmospheric cloak.

The quantity of water retained in the soil and its height or surface level varies with the season, supplies from underground sources, the aggregate voids, and the depth in the subsoil of the impermeable or water-supporting stratum. Thus on the one hand the voids may be fully charged, to the exclusion of air, with water to the level of the surface, and on the other hand the water level may be several hundreds of feet below the surface. The amount of moisture, as distinct from ground water, retained turns upon the facility of the soil particles for holding water by surface tension, a facility which, in a permeable soil with a free drainage outlet, determines the moisture content.

If the subsoil is of a pervious character and possesses a natural or artificial outlet, drainage ensues, the water level being regulated by the rapidity of the percolage; but it is rare for a sufficiently rapid discharge to take place in time of rainfall so as to prevent an increase in the height of the water level—hence the latter is variable and often discloses enormous differences between dry and

wet periods. Should an impervious stratum, either as a continuous bed or in the form of basins or depressions, underlie the water-holding soil and the latter have inadequate drainage, the water may be retained to the extent of outflowing above the surface in the wet season. With a non-porous stratum and complete absence of drainage the soil is saturated to the surface and forms a swamp, the only reduction being effected by surface evaporation.

Ground water is found as a more or less continuous underground lake at depths varying from a few inches to hundreds of feet. Land at the base of hilly ground may have its water level sustained by a hydrostatic head produced by infiltration of water at a higher level and at a great distance. Springs and artesian wells owe their flow to this factor.

The most notable variations are due to rainfall and percolation, which respectively bring about a rise and fall; but subsidiary causes of movement are fluctuations of soil temperature and barometric pressure resulting in air expansion and contraction: cooling of the ground air or reduction of pressure causing a rise, and expansion of air or increase of pressure a fall, in the water level. The water level may be gauged by the depth of water in district wells.

In many flat-surfaced districts large areas having a permeable subsoil possess a high subsoil water level maintained by the level of a watercourse serving as the natural means of drainage; and in places the substratum of impermeable soil may be so irregular in contour as to 'pond' and stagnate the water in cup-like depressions in which many organic impurities are retained and decomposed, with a marked deleterious effect upon the ground air in the soil interstices above the water level.

A well-drained soil—whatever its composition—is the warmer and healthier when compared with a wet soil of identical formation. A low water level is to be aimed at, but where this is unattainable excessive fluctuations are to be avoided, for it is better to have a site with a constant

water level within, say, 5 ft. of the surface, yet having an outlet permitting a steady flow through natural underground channels or laid drains, than a site where the level is sometimes considerably lower but subject to extreme fluctuations, or where the water is contained in a 'basin' or 'pond' so cupped as to prevent percolation.

Ground Air

The pores of the soil, unless waterlogged, are filled with air, and this air-content or 'ground air' (i.e. the air present in the soil between the subsoil water level and the surface of the ground) is seldom quiescent, a more or less constant interchange being effected with the air-cloak covering the surface of the soil. Of the causes influencing the volume of ground air a fluctuating subsoil water level is the most potent, an increase in the height bringing about expulsion of air from soil to atmosphere, and a decrease permitting impulsion by atmospheric pressure. Subsidiary movements arise from the expansion and contraction of the ground air on variation of the soil temperature, the application and withdrawal of barometric pressure, the infiltration of rain, and surface wind action.

The character of the ground air is determined by the soil constituents and the amount of contained moisture. Air from a saturated but drained soil is moist, and if the surface soil is freely and continuously supplied by capillary action with moisture from the water level, or if the latter is high, the expelled air is likely to be completely saturated, a condition resulting in a damp, and maybe cold, site.

In addition to moisture, the ground air can be charged with gases which are offensive and possibly prejudicial to health. Marshes and waterlogged soils containing a large percentage of vegetable debris, mudbanks, alluvial soils on the borders of streams, graveyards, soils overlaid with rank vegetation or charged with sewage from cesspools or drains, or made up of filth—such as offal, house refuse,

the contents of privies, &c.—produce a highly obnoxious ground air. Graveyards and soils charged with sewage and other animal matter emit sulphuretted hydrogen and other foetid gases. Marsh gas and sulphuretted hydrogen are the usual concomitants of decaying vegetable matter.

Ground air contains the irrespirable gas, carbon dioxide, largely in excess of that found in atmospheric air, with a reduced volume of oxygen.[1] It is not suggested that CO_2 in the percentages found is, *per se*, dangerous to health, but its presence in such large volumes is indicative of pronounced chemical changes in the soil constituents, and suggests the existence of other, including ill- or undefined, deleterious gases from the decomposition of organic matter.

Embedded vegetable matter decomposes more slowly than animal matter, and in all cases decomposition is assisted by heat and retarded by cold. In general, the more permeable and better aerated the soil the more rapid the decay of organic matter. This is exemplified in the case of graveyards, where decomposition quickly ensues in gravelly and other light and easily aerated soils, whereas in impermeable and cold soils such as clay the process is much slower. Gaseous emanations are experienced from comparatively dry and well-drained soils, but they are much more marked where the soil is waterlogged to within a few feet of the surface, especially where the water is stagnant or where there is a great variation in the subsoil water level.

The escape or forcing out of air from the soil points to the essential need that exists of maintaining the surface soil in a clean, healthy state, with freedom from putrescible organic matters and adequate drainage of the subsoil so that percolation can take place leaving the minimum amount of water in the pores: a need that is emphasized

[1] Foder found during observations at Buda Pesth mean average amounts respectively at 1, 2, and 4 metres of 10·2, 16·1, and 28·1 as compared with 0·04 parts in ordinary atmospheric air. *A Treatise on Hygiene and Public Health*, p. 321. Stevenson and Murphy.

by the constant liability of gases from unsealed ground surfaces beneath and around buildings to find their way into the latter by the air-movements set up through the action of fires or other heating agencies increasing the internal temperature above that of the external air.

Wind-conveyance of Effluvia and Infection

In the neighbourhood of low-lying marshy land, or land which has been subjected to excessive irrigation in the form of allowing water to stagnate in the subsoil—in which category some land treatment sewage disposal works can be placed—a site ordinarily regarded as healthy may be rendered unsuitable by being situated where the prevailing winds convey offensive odours and maybe miasma from malaria-producing ground. Sites at the head of a valley, even though elevated, may thus become a danger point.

In cities and their neighbourhood sites are sometimes rendered undesirable by the presence of dust, smoke, or effluvium-producing processes, such as offensive trades, brick and stone crushing, brick burning, gas manufacture, refuse destructors, and badly-conducted sewage disposal works; also by the existence of accumulations of house refuse,[1] night-soil, manure, and other refuse favouring fly-breeding. At sea-coast and riverside towns wind-carried effluvium is often borne from a badly-placed sewage outfall.

Altitude and Aspect

Elevated sites are generally cold and it can be appreciated that, given a favourable situation and aspect, the atmospheric surroundings tend to air-purity and physical invigoration. With positions on the side of a hill regard should be had to the route travelled by the winds impacting against the elevated surfaces. Fully exposed positions have the optimum air-movement, but are inclined to be

[1] In addition to effluvium nuisance arising from the decomposition of organic matter, large heaps of house refuse 'fire' by spontaneous combustion, and offensive odorous smoke is often wind-conveyed for a long distance from the place of deposit.

bleak if facing the north or east. Land below or near sea-level or contiguous to muddy river banks, estuaries, and saltings can be looked upon with suspicion, commonly being damp, provocative of much fog and atmospheric moisture, and highly charged with putrefactive organic matter responsible for unhealthy ground air.

In the northern cold and temperate zones sites on the northern slope of a hill or other elevation are often cold and sunless. An open southern aspect gives the maximum intensity and duration of sunshine, and is, in every respect, preferable to a sheltered position.

Soil Comparisons

Of the local circumstances fundamentally affecting sites, the condition of the soil in respect of geological structure, air, and water content is probably the most vital, as it determines in no small degree the character of the adjacent atmosphere.

Granite, slate, and other similar primitive rocks are practically impervious to moisture, the entrance of which into the mass is limited to crevices in the formation. Consequently they are dry, practically free from air-emanations, but cold by reason of their high specific heat.

Limestones and permeable sandstones are healthy if the surface is well drained, but the latter may be damp if supported on a clay subsoil.

Clay is retentive of moisture and possesses good heat-conducting power; therefore it is damp and cold and surrenders much moisture to the atmosphere. With a good surface fall it is healthier than many sands and gravels containing organic matter.

Chalk is similar to clay in respect of temperature and moisture, but is often so fissured as to allow the infiltration of polluting liquids. Unmixed with clay it is healthy, but cold.

Dry sandy and gravelly soils are warm and healthy except where polluted by sewage or other putrescible

organic matter which is readily absorbed into the mass. If the subsoil is waterlogged these soils are damp and give off considerable volumes of moisture and ground air and consequently are unhealthy. Gravel of good depth where the elevation is high and the soil drained provides site conditions second to none.

Alluvial, peat, and marsh soils contain a large percentage of water and decomposable organic debris, and freely emit moisture together with ground air of doubtful quality. Usually they are unhealthy.

Properly cultivated soils are generally healthy if adequately drained, but irrigated land gives off much moisture and ground air and is unhealthy.

'Made' Ground

The raising of the level of low-lying ground and filling up of natural depressions, quarries, gravel-pits, and other excavations with night-soil, fish and other offal, house, street, and market refuse is a prolific cause of nuisance from smell and flies during the progress of the deposit, and from the emission of offensive ground air during at least part of the period occupied in the decomposition or breaking-down of the organic matters, a condition accentuated with a fluctuating subsoil water level. If, as happens on occasion, refuse is tipped into water, the evolution and liberation of offensive gases ensue. Drainage from such deposits may also endanger the purity of local water supplies.

Bad Sites

Positions to be avoided may be summarized as:

(*a*) Sites affected by winds blowing over marshy land and other odoriferous spots, such as muddy streams and ditches.

(*b*) Sites on a steep slope and ground at the base of a slope or in deep valleys receiving drainage from upper or higher levels, or where vegetation is rank.

(*c*) Muddy sea beach; alluvial soil forming banks of rivers, ponds,

and lakes, particularly where subject to intermittent flooding; saltings; peaty and marshy ground; and sand and gravel subsoils full of stagnant water.

(*d*) Sites immediately adjacent to graveyards and offensive trade premises.

(*e*) Ground made up with house refuse, faecal or other noxious matter.

Ideal Sites

An ideal site should have the following qualifications:

(*a*) Healthy local climate with protection from north and east winds.

(*b*) Space for the free movement of air, and so situated as to receive the maximum amount of sunshine.

(*c*) Dry, warm, and porous soil well drained.

Protective and Improvement Measures

The ideal position cannot always be found, and hence it becomes necessary to improve existing conditions and thus render them as healthy and comfortable as practicable. Means to this end include the following:

Protection against cold-, effluvium-, and infection-conveying winds. For protection against cold north and east winds a belt of trees is useful, but it should be at a sufficient distance to allow the access of sunshine to, and ample perflation around, any buildings. Experience has shown that a wood or belt of trees will also act as a barrier to the passage of infective germs, whether air-borne or carried by flies. For localized conditions the dissemination of dust can often be prevented by the erection of a suitable screen.

That air-conveyed offence may be expected from particular trade processes is recognized by the legislature. In London it is an offence to erect a dwelling-house within 50 ft. of a building used for blood-boiling, bone-boiling, or any other like offensive or noxious business;[1] and, by by-law, offensive processes in recognized noxious trade premises must be conducted in closed chambers and adequate

provision made for preventing effluvium escaping to the outer air.[1] Urban authorities may also make by-laws in order to prevent or diminish noxious or injurious effects from offensive trades.[2]

Further, nuisance from deposits or accumulations on any premises, and from smoke (including soot, ash, grit, and gritty particles) from chimneys of trade premises, can be dealt with. Legal proceedings may be instituted by sanitary authorities for effluvium nuisance from trade premises whether such premises are within or without their district.[3]

Other centres postulating air-contamination which may be referred to are burial grounds and hospitals for small-pox. The provision of a cemetery within 100 yds. of a dwelling-house is proscribed except with the consent in writing of the owner, lessee, and occupier. In burial grounds subject to the Burial Act, 1855, a grave must not be within 100 yds. of a dwelling-house without the consent in writing of the owner, lessee, and occupier.[4]

A memorandum issued by the Minister of Health in 1926 [5] directed attention to the possible dangers to public health from burial places through contamination of (1) air, by gaseous and volatile substances, and (2) drinking water, by liquid products of decomposition. To obviate these risks the position chosen should therefore be in an open situation distant from dwellings and subterranean sources of water supply, the site should consist of suitable soil adequately drained, and burial be at a sufficient depth below the surface.

The Minister of Health stipulates by memorandum[1] that: 'In view of the frequently demonstrated liability of small-pox hospitals to disseminate that disease to neighbouring communities, and in order to lessen the risk of such occurrence,' the site 'must not have within a quarter of a mile of it either a hospital, whether for infectious diseases or not, or a Poor Law institution, asylum, or any similar establishment, or a population of as many as 200 persons', nor 'have within half a mile of it a population of as many as 600 persons, whether in one or more institutions or in dwelling-houses'.

Cultivation of Surface Soil

Growing vegetation will reduce the water content of the soil, for it is estimated[2] that 200 lb. of water are evaporated in forming 1 lb. of woody fibre. Wet soils, if uncultivated, are better left with a hard surface than put into a condition of tilth, as the former permits much more evaporation. Turfing, or the growth of short grass, is also beneficial as it reduces the percolation of rain into, and increases the rate of evaporation from, the soil. Trees prevent the access of rainfall to the surface, assist the retention of water in the soil, and *per contra* evaporate an enormous quantity of water out of the soil.

Surface Grading and Filling

Grading and drainage of the surface may be carried out and land depressions, ponds, and pools filled up so as to prevent the accumulation of stagnant water. Where the filling up of a pond is impracticable it should be kept free from rank vegetation, muddy banks, and collections of rubbish and debris which harbour mosquito larvae. If mosquito-infested, definite steps ought to be taken to put a stop to breeding. Certain fish are active exterminators of larvae and their cultivation in suitable circumstances

[1] Memorandum *On the Provision of Isolation Hospital Accommodation by Local Authorities*, January 1924.
[2] *Healthy Dwellings*, p. 13. Galton.

has resulted in the elimination of the pest.[1] Petroleum and various other oils can be used as chemical larvicides, which act 'by intercepting the air from the larvae requiring oxygen'.[2] Kerosine and a mixture of equal parts of kerosine and pesterine are extensively used, about 3 gals. per 10,000 sq. yds. being required, applied by means of an ordinary garden spray. Chlorinated lime mixed with crude petroleum is also useful for destroying the larvae and preventing mosquitoes from laying their eggs. Repeated applications of these larvicides are needed to prevent breeding, as the medium is likely to be washed away during showery weather, and the practice has the disadvantage of killing small fish, snails, &c., who are the natural enemies of the larvae, and if the water of a pond or pool so treated is used by man or cattle for drinking there is risk of poisoning.

For the filling up of surface depressions and excavations innocuous rubbish is preferable. If filth, dust, ashes, or rubbish likely to give rise to nuisance is employed, the period of deposit is best restricted to the cold months, and in any case it is desirable to adopt the precautions suggested by the Ministry of Health,[3] viz.:

1. Deposit to be made in layers.
2. No layer to exceed 6 ft. in depth.
3. Each layer to be covered on all surfaces exposed to the air with at least 9 in. of earth or other suitable substance.
4. No refuse to be left uncovered for more than seventy-two hours from the time of deposit.
5. Sufficient screens or other suitable apparatus to be provided where necessary to prevent any paper or other debris from being blown by the wind from the place of deposit.
6. Deposit of any filth, dust, ashes, or rubbish likely to cause nuisance in water to be, so far as practicable, avoided.

[1] The 'top-minnow' from Hawaii has been found to be the most successful mosquito-eating fish. A. G. Millott Severn, *Journal of the Royal Sanitary Institute*, vol. xlvi, no. 13, p. 625.

[2] *Hygiene and Public Health*, p. 316. Ghosh and Das.

[3] *Refuse Tips.—Suggested Precautions in depositing Filth, Dust, Ashes or Rubbish likely to give rise to Nuisance*. Issued by the Ministry of Health, July 1922.

7. Reasonable precautions to be taken to prevent the breaking out of fires and the breeding of flies and vermin.
8. Material consisting entirely or mainly of fish, animal, or other organic refuse forthwith to be covered with earth or other equally suitable substance at least 2 ft. in depth.
9. Tins or other vessels or loose debris likely to give rise to nuisance not to be deposited in an exposed position.
10. Each layer laid and covered with soil to be allowed to settle before next layer is added.
11. Wherever practicable surface of tip not to be raised above the general level of the adjoining ground.

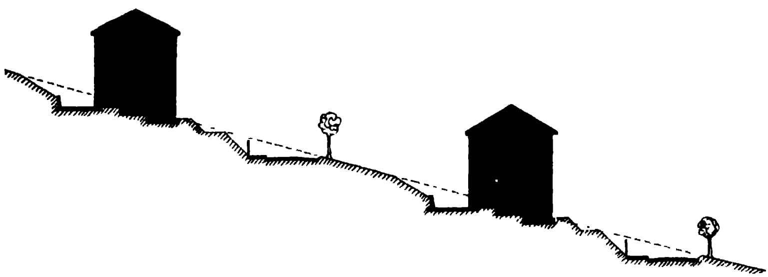


FIG. 1. One method of regrading surface contour of steep slope.

Where necessary the surface contour should be regraded so as to divert the surface water and water outcropping from a hillside or land of a higher level. If the site is on a steep slope, regrading of the surface in some such manner as is indicated in Fig. 1 should be undertaken.

Drainage of Subsoil

For subsoils that are either waterlogged or insufficiently provided with natural drainage, artificial drains should be laid to remove quickly and adequately the subsoil water. The lower these drains are the better, but as a practical proposition it is usual to limit the necessary excavations to about 6 ft. from the surface.

With extensive sites having a fall to a stream or water-course a system of gravitating lateral and intersecting sub-soil drains may be so arranged as to discharge into the stream above the natural water level. If this is impractic-

able the outfall can be designed with a well or sump to which a pump or an automatic ejector is connected so as to lift the water to a level at which it can be discharged into the nearest watercourse or drain. For large areas successful results can be attained by using a pump worked by a windmill; but ejectors or lifts, primarily designed for lifting sewage, of the types illustrated by Figs. 315 and 316, are more dependable, the action of the apparatus being automatic and regulated by the level of the water in the sump. The size, number, and arrangement of the drains must be governed by the nature and extent of the site under treatment. Pipes 2 to 6 in. in diameter are commonly employed.

Lateral and intersecting drains are variously laid from 2 ft. 6 in. to 6 ft. in depth in trenches from 10 to 40 ft. or more apart according to the nature of the soil and the volume of water to be removed. In heavy clay soil the pipes need to be fairly close, whilst considerable space may be allowed if the subsoil consists of gravel or sand. For the former, a depth of 2 ft. 6 in. to 4 ft. and a spacing of 30 to 40 ft. is often adopted, with diameters of 3 to 4 in. for the main and 2 to 3 in. for the branch drains. (See Chapters XIV and XVI for the form and construction and discharging powers of pipes.) Clay sites can be vastly improved by digging the soil out to a depth of 4 to 6 ft., converting into ballast by burning, and then replacing with a sufficient number of under-drains.

The Model by-laws specify [1] 'the subsoil of the site of *a building shall, wherever the dampness of the site renders* the precaution necessary, be effectively drained by means of earthenware field pipes or other suitable pipes properly laid to a suitable outfall'.

Dwelling-houses on Low-lying Land

The erection, re-erection, or adaptation of a building as a dwelling-house on land of which the surface is below

[1] Urban, Series IV, 1925.

the level of Trinity high-water mark (i. e. 12 ft. 6 in. above ordnance datum), and which is so situate as not to admit of being efficiently drained by gravitation at all times into an existing sewer, is prohibited in London, except with the consent of the county council and in accordance with such regulations as may be prescribed.[1] By a regulation it is made unlawful to place the underside of the lowest floor of any permitted building at such a level as will render it liable to flooding, and every such building must be efficiently and properly drained.

A useful provision is also contained in the Model by-laws, as follows:[2] 'Where the intended site of a new building has been or has formed part of a clay-pit, or where by reason of excavation and the removal of earth, gravel, stones, or other materials from such site the whole or any part of the surface thereof is at such a level as may render the elevation of the whole or part of the existing surface of the site necessary for the prevention of damp in any part of any building to be erected thereon, the person who shall erect the building shall properly deposit upon the site or upon such part thereof as, for the purpose aforesaid, may require elevation a layer or layers of sound and suitable material sufficient to elevate so much of the site as shall be within the external walls of the building to an adequate height.' Further, 'where the intended site of a new building is (at a height less than ..... feet above ordnance datum) (within an area bounded by .....), the person who shall erect the building shall properly deposit upon the site a layer or layers of sound and suitable material sufficient to elevate so much of the site as shall be within the external walls of the building to a height of at least ..... feet above the ordnance datum.'

Where this last clause is adopted it is pointed out that 'the Council in filling it up should carefully consider the requirements of their district in the light of local know-

[1] London County Council (General Powers) Act, 1920.
[2] Urban, Series IV, 1925.

ledge as to the height to which floods may extend and the area or areas liable to be affected by them. In districts in which the water levels vary little, as in those of small extent or in flat districts near to the sea or to a tidal river, it may often suffice to specify only the height above ordnance datum below which the by-laws come into force without defining an area, otherwise than by the height. But in districts of varying level, in which the liability to flooding of different parts is affected by local conditions other than the height above sea level—as by obstructions to the flow of water in a river—it may be necessary to define an area comprising the part liable to be flooded, and to limit the by-law to this area. In some districts containing a considerable length of river course it may indeed be necessary to define two or more such areas, and to specify a different height in each area.'

Buildings on 'Made' Ground

The erection of buildings upon land made up of offensive material or upon which such material has been deposited is statutorily barred in urban and rural districts.[1] In London a by-law provides that: 'No house, building, or other erection shall be erected upon any site which shall have been filled up or covered with any material impregnated or mixed with any faecal, animal, or vegetable matter, or which shall have been filled up or covered with dust, or slop, or other refuse, or in or upon which any such matter or refuse shall have been deposited, unless and until such matter or refuse shall have been properly removed, by excavation or otherwise, from such site. Any holes caused by such excavation must, if not used for a basement or cellar, be filled in with hard brick or dry rubbish, or concrete or other suitable material to be approved by the District Surveyor.'[2] A similar provision

[1] Public Health Acts Amendment Act, 1890. Subject to the adoption of Part IV of the Act.

[2] By-law made under the Metropolis Management and Building Acts Amendment Act, 1878.

is made for excavations within 3 ft. of the outside of the site of a house, building, or other erection.[1]

Prevention of Soil Emanations

The only possible method of preventing emanations is to cover the site with a layer of jointless and impervious material. In the case of the actual ground upon which the building is to be erected this course is imperative; and where the site is undesirable or open to suspicion from any of the causes previously mentioned, and particularly if it consists of 'made-up' ground, the surface adjacent to the building should be similarly protected.

The composition of the covering material is sometimes left to the discretion of the officers of the local authority. The Model by-laws[2] provide, in the case of a new domestic building in an urban district, that the whole ground surface within the external walls of such building shall be properly asphalted or covered with a layer of good cement concrete at least 6 in. thick, or 4 in. thick if properly grouted; a requirement modified for rural and intermediate districts, insistence upon this being only where 'the dampness of the site or the nature of the soil renders such a precaution necessary'. In London it is compulsory that 'the site of every house or building shall be covered with a layer of good concrete, at least 6 in. thick and smoothed on the upper surface', such concrete to be composed of 'clean gravel, broken hard brick, properly burnt ballast, or other hard material to be approved by the District Surveyor, well mixed with freshly burned lime or cement in the proportions of one of lime to six, and one of cement to eight, of the other material'.[3] (See Chapter V, p. 81, as to site coverings of waterproofed cement concrete.)

Sanitary authorities are empowered to make by-laws as to the 'paving of yards and open spaces in connexion with

[1] By-law made under the London County Council (General Powers) Act, 1890.
[2] Urban, Series IV, 1925. [3] See p. 19, note 2.

dwelling-houses',[1] and as such by-laws are presumably intended to prevent or remedy insanitary conditions, the covering of unsuitable soil in the vicinity of the dwelling may well be considered as coming within the description used. One such code stipulates[2] that, where it is necessary for the prevention or remedy of insanitary conditions, a yard or open space attached to a dwelling-house shall be 'properly paved with a hard durable and impervious pavement of flagging, paving bricks, or tiles evenly and closely laid upon a sufficient bed of good concrete, mortar, sand, or other suitable material, and properly jointed, or with cement concrete evenly floated with good cement to a smooth face, or with good asphalt or tar paving on a proper foundation, and so sloped to a properly constructed channel as effectually to carry off all rain or waste water therefrom'. This code also stipulates for new dwelling-houses 150 sq. ft. of such paving adjoining the external wall in the rear or side of building, extending, where practicable, to a depth of 10 ft. from such wall or walls.

Selection of Sites

In the selection of sites for special uses attention is directed by the controlling, approving, or supervisory authority to various needs or suggestions as follows:

Housing Schemes [3]

(*a*) Relation to existing or contemplated residential and factory sites.

(*b*) The suitability of the subsoil and the aspect of the site if sloping. Northern sites are not desirable, and sites sloping steeply to the north should not be selected.

(*c*) Amenities of the site, trees, fertility of the soil for gardens, prospects, &c.

(*d*) Open spaces in the neighbourhood and adaptability of parts of site for this purpose.

[1] Public Health Acts Amendment Act, 1890, and Public Health (London) Act, 1891. See also Public Health Acts Amendment Act, 1907.

[2] By-laws made by the Urban District Council of Acton (Middlesex).

[3] *Manual on the preparation of State-aided Housing Schemes*, 1919. Local Government Board.

(*e*) Convenience and economy in the provision of sewerage, water supply, and other services.

In the case of rural housing especially, the questions of adequate water supply and drainage will be important factors in the choice of sites.

Public Elementary Schools [1]

The site should be:

(1) In an open situation, and have no undesirable surroundings; not exposed to noise or dust from roads, streets, tram-lines, railways, or works; such that the building can either be set well back or have its class-rooms on a side away from the street or road, so that there may be no difficulty in keeping their windows open, and allow of classes being taken in the playground.

(2) Convenient for access. Entrances and exits on to main roads as far as possible to be avoided. Where unavoidable, barriers should be provided as a safeguard.

(3) Open to the sun, both for the sake of the general health of the scholars and teachers, and because the ventilation of the building is then easier. The best aspect possible for the class-rooms is south-east. In the warmer parts of England east may be a better aspect than south. Rooms which face south-west get little sun in the early part of the day, while subsequently they are apt to get too much. Windows which look to quarters other than these should, so far as possible, be those of corridors, staircases, cloak-rooms, cookery rooms, and the like.

(4) Sufficiently large, open, and level to allow all the rooms to be on the ground floor. It is in any case desirable that the building should be on not more than two floors. A building on three floors is open to many objections and should only be necessary in special circumstances, as, for example, where land is very costly or where it is otherwise impossible to get adequate area for playgrounds.

Further:

(5) The most should be made of any natural advantages which the site may possess. Pleasant views should be left open instead of

[1] *Building Regulations for Public Elementary Schools*, 1914. Board of Education. These regulations are also applicable in certain particulars to schools for blind, deaf, defective, and epileptic children. See *Regulations for Special Schools*, 1917.

being shut off by high boundary walls. If it is consistent with the proper lighting of the school, any large trees may well be preserved to give shade in summer to open-air classes.

(6) In laying out the ground every opportunity should be taken to provide a clear space for play, facilities for open-air teaching, and, where space permits, for school gardens and for organized games such as cricket and football.

(7) The site must include space for a playground. Where the site is expensive, the provision of a playground on the roof of the school buildings has been found in some cases to be a satisfactory device.

(8) (*a*) To provide space for a playground the minimum area for the site should be reckoned, in the absence of exceptional circumstances, at a rate of a quarter of an acre for every 200 children, irrespective of any space required for a teacher's or caretaker's house, for Special Subjects Centres, or for instruction in gardening. (*b*) If the school is of more than one story, or if a roof playground is provided, the area can be proportionately reduced.

Secondary Schools [1]

The suggestions of the Board of Education embody paragraphs 1, 3, and 5 as set out for elementary schools with:

(*a*) Convenient access to site.

(*b*) The provision of suitable plots for botany, gardening, and other natural history work.

(*c*) A playground with an area of 50 sq. ft. per head.

Isolation Hospitals [2]

The site should be convenient of access, and, as far as practicable, central for the population and area which it is to serve; but not in a very populous neighbourhood. (See p. 14 as to small-pox hospitals.) It will be of much convenience if sewers and a public water service are available; but, if not, a sufficient supply of wholesome water must be provided and adequate arrangements made for the treatment of the sewage, due care being taken to avoid pollution of any well or spring or of any river. The site should be

[1] *Building Regulations for Secondary Schools*, 1914. Board of Education.

[2] Memorandum *On the Provision of Isolation Hospital Accommodation by Local Authorities*. 1924. Ministry of Health.

in a healthy and open situation with a dry subsoil; preferably of a compact and regular shape; and not too steep. Its area will depend upon the size of the hospital, and except in the case of a very small hospital should rarely be less than two acres. More land will be needed if the sewage has to be disposed of on the site.

Every building which is to contain infected persons or things should be at least 40 ft. distant from the boundary.

Voluntary Hospitals[1]

In the selection of the site, the following considerations must be taken into account:

(*a*) Area.
(*b*) Accessibility.
(*c*) Elevation and environment.
(*d*) Levels, contour, and aspect.
(*e*) Subsoil and surface drainage.
(*f*) Drainage and sewage disposal facilities.
(*g*) Water supply and lighting.
(*h*) The probable developments around the site, e.g. town-planning schemes or any industrial expansion on the adjoining lands.

The site should command a maximum of sunshine and pleasant outlook and be removed from factories or buildings likely to pollute the air. Protection from northerly and easterly winds is desirable. Low-lying or damp sites should be avoided, and as far as possible an open site standing above neighbouring buildings sought. The levels and contours of the site play an important part in the orientation or aspect of the buildings. A slight fall from north-east to south-west is preferable to any other. The subsoil should be light and porous. Facilities for easy drainage into a public sewer should be taken into account, as, if no sewer is available, the difficulties and cost of disposing of the sewage on the site must be carefully considered. Usually this will entail an increased area of ground and, wherever possible, the extension of a public sewer will be preferable. An abundant supply of good water is essential and should preferably be obtained from a public source.

[1] Memorandum *On the Construction of Voluntary Hospitals*, 1926. Voluntary Hospitals Commission.

II

LIGHT- AND AIR-ENVIRONMENT OF BUILDINGS

THE provision of sufficient open space to permit the impingement of sunshine on, free air-movement around, and access to the interior of buildings of both sunshine and air has an important bearing upon their healthiness. In judging the effects of environment upon health it is difficult to divorce external and internal conditions, as the former to an indefinable and possibly immeasurable extent determine the character of the latter. The crowding of communities on a restricted ground area is no modern innovation, for towns created in medieval times present notable examples of narrow streets and limited open-air surroundings. Within recent times the economic necessity of accommodating an increasing number of persons for residential or business purposes, or both, has accentuated crowding by the re-erection on cleared sites of buildings of greater height and the utilization of many of the remaining open spaces to such an extent as to lessen the opportunities for the access of light and air.

In cities where the area of land available for development is restricted and the demand great—factors which increase the money value of sites—it is not to be wondered at that the fullest possible advantage is taken of the commercial aspect without much regard to hygienic necessities. Hence narrow streets, lack of rear space, and high buildings join in shutting out light and air and inflicting on persons whose livelihood depends upon sojourn in such an environment conditions inimical to their welfare. In London and many other cities, thousands of offices warehouses, workshops, and dwellings in the inner ring are conspicuously lacking in direct light from the sky, are entire strangers to the rays of the sun, and their use on the

brightest of summer days is dependent upon the provision of means of artificial lighting. Further, the atmospheric surroundings are close and deficient in movement and

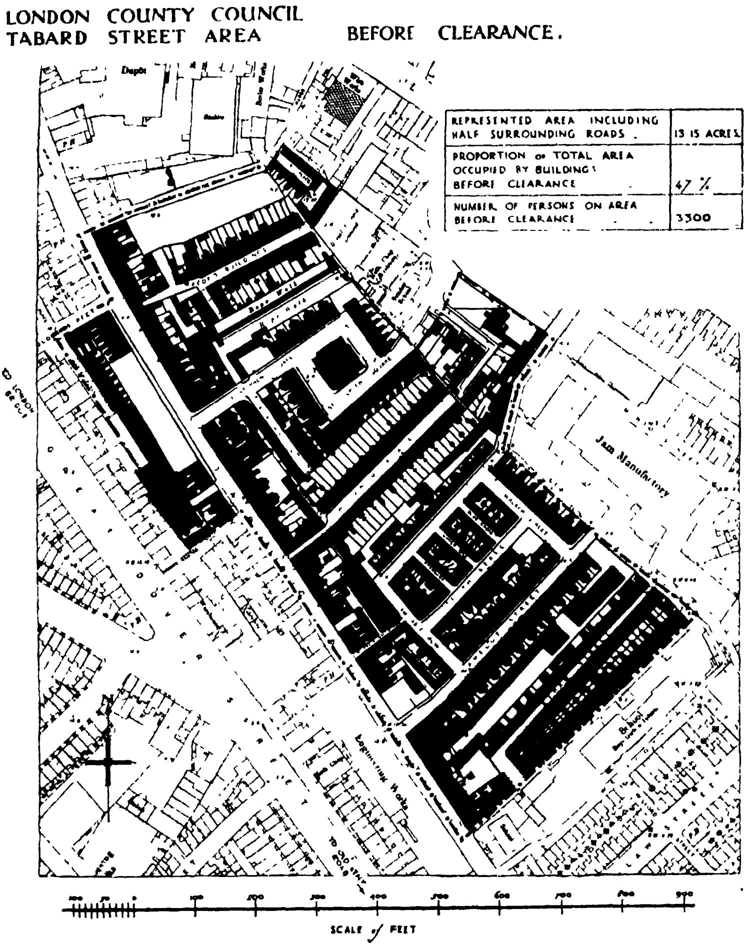


FIG. 2. An insanitary area with relatively small 'shut-in' open spaces.

cooling power, with a much worse correlative state in the interior of the buildings.

These conditions are not limited to the innermost ring of a city, for many cases can be cited elsewhere of buildings

so crowded together, with inadequate open space and shut in by obstructive buildings, that natural lighting and free air-movement are seriously interfered with.

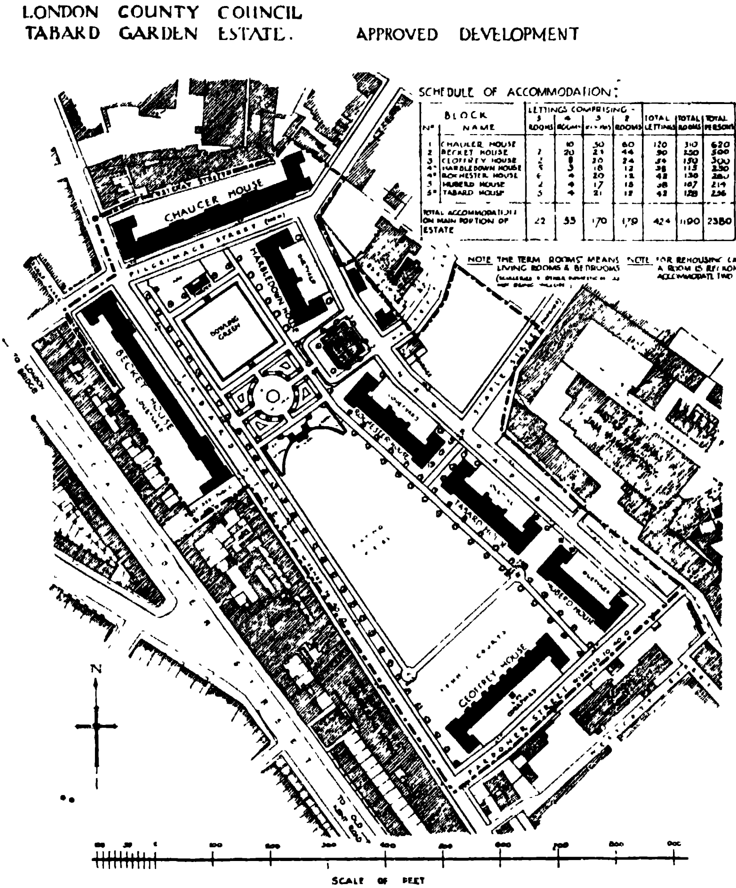


FIG. 3. Area shown in Fig. 2 as reconstructed.

In some centres the widening of streets for traffic purposes has effected an improvement in the atmospheric surround and content of buildings; the natural lighting of interiors has also benefited, but not to the same extent as the atmospheric state owing to the fact that the widening of streets has brought the corollary of new buildings carried to a greater height. Other public improvements

have secured a better lay-out of areas with increased opportunities for the access of light and air; the clearance of slum areas has resulted in the sweeping away of premises

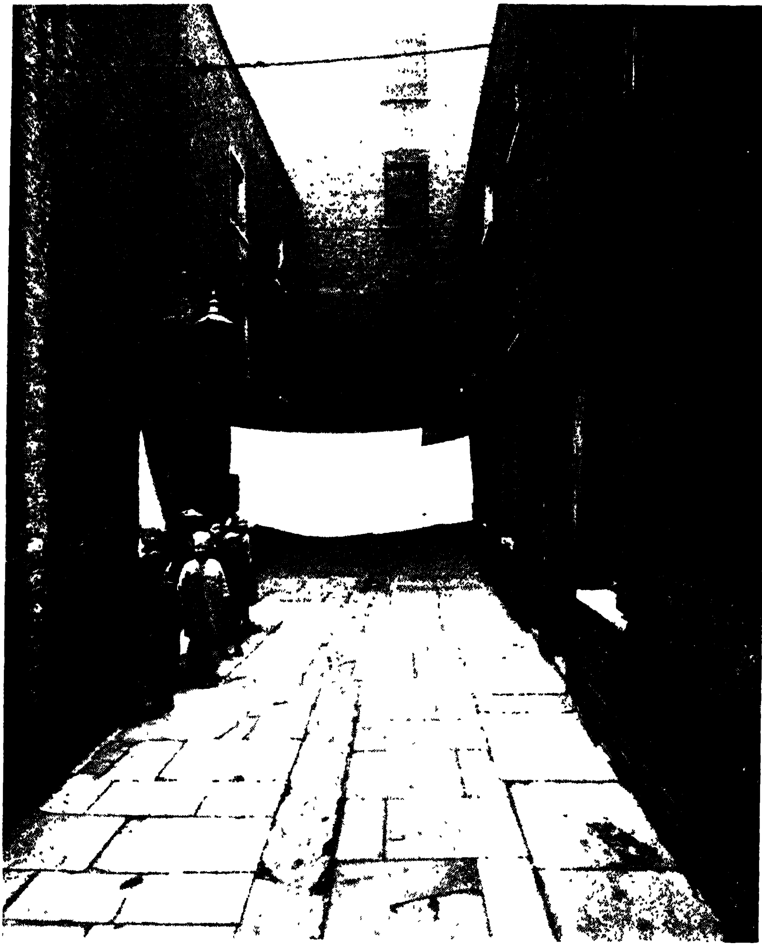


FIG. 4. Court with obstructive buildings shutting out air and sunshine.

insanitary in themselves and rendered still more so by restrictive surroundings; and much has been done, especially in the past decade, to secure better housing conditions, not alone by removing slums, but also by the

provision of new and better planned dwellings. The problem of securing an amendment of many of the unsatisfactory conditions, however, is a long way from solution.

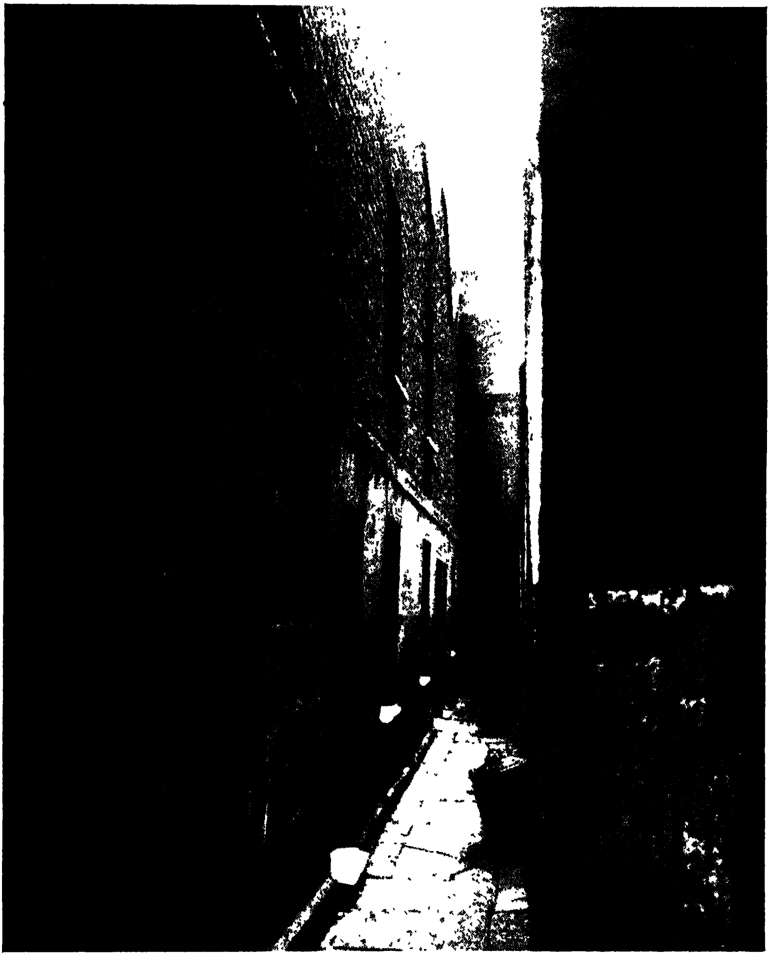


FIG. 5. Narrow court with obstructive buildings.

Improvement of individual premises will help, but the main hope of the future appears to be in the direction of obtaining the lay-out of redeveloped and newly developed areas on hygienic lines.

Fig. 2 is illustrative of an insanitary area (since cleared—see Fig. 3), and shows the relatively small open spaces and the impediments to perflation due to their 'shut-in' character. It is significant that of the total area of 13·15 acres, which included half of the surrounding streets and the whole of the interior streets, the buildings occupied no less a proportion than 47 per cent. In Figs. 4 and 5 are given excellent examples of narrow courts or cul-de-sacs with close and obstructive buildings shutting out light and air.

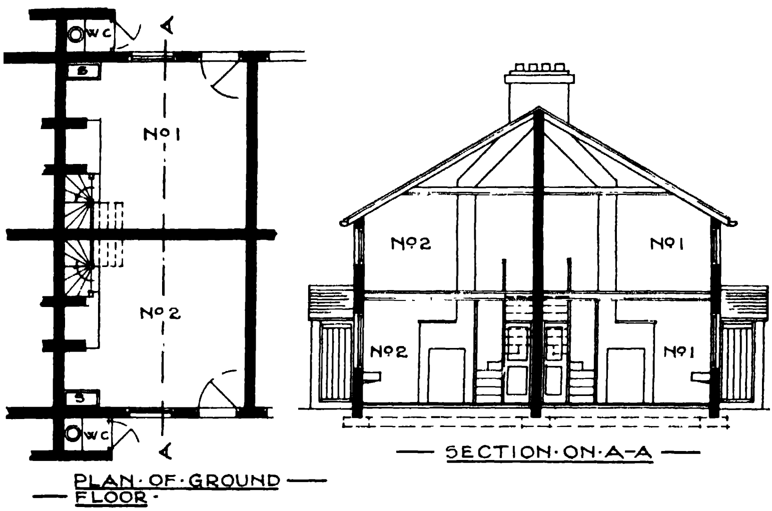


FIG. 6. Two-story back-to-back houses unprovided with means of 'through' ventilation.

Taking individual premises, a prominent instance is found in back-to-back houses (Fig. 6), a type of construction much in evidence in some parts and indicating in the clearest way possible the impracticability of obtaining, what is so essential to healthiness, 'through' ventilation.

Restriction of air-movement around buildings is not confined to city and crowded urban districts, for many illustrations can be found in rural and seaside surroundings, as in Fig. 7, which shows dwellings built so close up to the side of a hill as to impede air-movement around and through the buildings.

The Impress of Environment on Health

The effect on health of confinement for many hours day after day in offices and other similar buildings lacking a sufficiency of natural light and an adequate and pure air service is not easily ascertained, but with dwellings sufficient data are forthcoming to indicate the harmful results of continued occupation. Ocular demonstration afforded by the debilitated appearance of many of the occupants, particularly young children, is effectively supported by the death-rates, and notably by the infantile mortality. Evidence tendered at an official inquiry in connexion with a typical area represented as insanitary under the Housing Acts is not without significance in this respect:

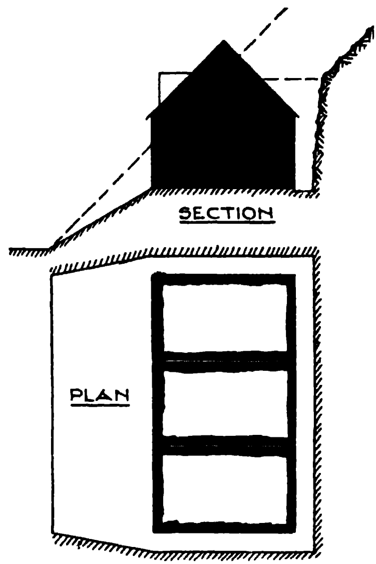


FIG. 7. Dwellings with restricted air-surround due to proximity of hill-side.

	Whole of the Borough.	Area represented.
(1) Area in acres	642	14·2
(2) Inhabited houses	11,535	580
(3) Average population	100,130	4,728
(4) Density of population	156	333
(5) Birth-rate	26·5 per 1,000	29·6 per 1,000
(6) Infantile mortality	149·0 ,, 1,000	188·0 ,, 1,000
(7) Death-rate	20·6 ,, 1,000	22·8 ,, 1,000
(8) Zymotic death-rate	2·3 ,, 1,000	4·2 ,, 1,000

Note: Nos. 3 to 8 are the averages for six years.

For another and possibly more emphatic illustration Dr. King Brown may be quoted:[1] 'I have recently con-

[1] *Climate of a Big City and the Dwellings of the Poor*, Dr. King Brown.

demned an insanitary area of 3·9 acres which has 151 dwelling-houses with a population of 1,035, consisting of 234 families. The average general death-rate for 10 years was 24·6 per 1,000 living, against 17·5 for the rest of the Borough for the same period. The death-rate for respiratory diseases during this period was 6·57 per 1,000 living, as compared with 3·9 for the small whole Borough.. . . . The infantile mortality (i.e. deaths of infants *under* one year) was 182 per 1,000 births, as compared with 129. for the rest of the Borough. . . . I look upon the infantile mortality as the best human index of the "private climate" of a house, since, for the first year of life, the child in the slums has little experience of any other. The 151 houses are of the ordinary terrace or cottage type containing from 2 to 8 or 10 rooms, the majority having from 4 to 6 rooms. The width of the streets varies from 8 to 15 or 20 ft. Many of them are cul-de-sacs, and some of the houses are back to back. The spaces at the rear of the houses or yards are small, and do not provide much space for sunlight. The back-to-back houses have no yards. The ages of the houses vary from 60 to 200 years. The rooms are small, their capacity varying from 500 to 1,000 cu. ft., the majority of the rooms being only 700 to 800 cu. ft. The height of the ceilings varies from 6 ft. to 7 ft. 6 in., a very common height being 7 ft. Most of the rooms open direct into the open air, but a few do not. The staircases are generally central and are mostly unlit and unventilated.'

Well-authenticated instances of unhealthy conditions in ill-ventilated houses are available. One striking example relates to back-to-back houses referred to in a report by Dr. Darra Mair dealing with the village of Marley Hill in Whickham Urban District, Durham.[1] The report shows that in the decennium 1896–1905 the average annual death-rate from all causes was 16·0 per 1,000 living in

[1] Dr. L. W. Darra Mair's Report to the Local Government Board on the Sanitary Circumstances of the Whickham Urban District, with special reference to its Housing Accommodation generally, and to certain Back-to-Back Houses at Marley Hill in particular. 1907.

groups of back-to-back houses, compared with 12·6 in the rest of the village, and the estimated average infantile mortality per 1,000 births, 221 in the back-to-back houses as against 147 in the rest of the village, and this notwithstanding that the back-to-back houses 'are mainly in rows, or groups, but almost without exception each row or group is isolated, and has an abundance of air space'.

Many similar examples to the foregoing could be adduced of groups of houses whose history unmistakably and invidiously places crowded, ill-lighted, and ill-ventilated dwellings on a lower plane of healthiness than those having free air-movement around and through the buildings.

Statutory Remedies for Unhealthy Surroundings, &c.

Under the Housing, &c., Acts[1] power is given to local sanitary authorities to improve insanitary housing conditions, and provide better dwellings and surroundings. These powers embrace:

(1) Improvement schemes for the rearrangement and reconstruction of streets and houses within areas where:

(*a*) Any houses, courts, or alleys are unfit for human habitation; or

(*b*) The narrowness, closeness, and bad arrangement or the bad condition of the streets and houses or groups of houses within such area, or the want of light, air, ventilation or proper conveniences, or any other sanitary defects, or one or more of such causes are dangerous or injurious to the health of the inhabitants either of the buildings in the said area or of the neighbouring buildings.

(2) The closing of houses unfit for human habitation.

(3) The removal of an obstructive building (although not in itself unfit for human habitation) if so situate that by reason of its proximity to or contact with any other buildings it:

(*a*) Stops or impedes ventilation, or otherwise makes or conduces to make such other buildings to be in a condition

[1] Housing, Town Planning, &c., Acts, 1925.

unfit for human habitation or dangerous or injurious to health; or

(*b*) Prevents proper measures from being carried into effect for remedying any nuisance injurious to health or other evils complained of in respect of such other buildings.

(4) The preparation of town-planning schemes as respects any land in course of development or that appears likely to be used for building purposes with the general object 'of securing proper sanitary conditions, amenity, and convenience in connexion with the laying out and use of the land and of any neighbouring lands'.

Fig. 3, p. 27, shows the replanning of the insanitary area illustrated by Fig. 2, and is an example of the improvement effectible under the Acts named above.

Statutory Requirements in respect of Open Spaces about Buildings

Urban authorities may make by-laws relating to the level, width and construction of new streets, the sufficiency of the space about buildings to secure a free circulation of air and the ventilation of buildings, and to prevent the alteration of buildings in such a way that if at first so constructed they would have contravened the by-laws;[1] they may prescribe also the line in which any rebuilt or altered building shall be erected facing a street, and prohibit the erection or bringing forward of any building beyond those on either side.[2]

The power of making by-laws as to the sufficiency of air space may be adopted by a rural authority, and the Minister of Health can invest such authority with urban powers.[3]

In London the sanctioning of the formation of new streets, the enforcement of general lines of buildings, the

[1] Public Health Acts, 1875, 1890, and 1925.

[2] Public Health Acts, 1875 and 1925, and Public Health (Building in Streets) Act, 1888.

[3] Public Health Acts, 1875 and 1890.

construction of buildings and the sufficiency of air space about them come within the duties of the County Council.[1]

Open Space in front of Buildings
Width of Street

The Model by-laws[2] prescribe the following conditions for new streets:

Length in feet.	*Width in feet.*	*Distance in feet of main wall of building (the building line) from centre line of street.*	*Building line in feet from boundary.*	*Restrictions.*
(*a*) Carriage roads to be used as principal approach or means of access to buildings:				
Exceeding 1,000	36			
Not exceeding 1,000	30	30	15	
300	24	25	13	
1,000	26	30	17	Domestic buildings, and buildings on one side of street only.
300	21	25	14·5	do.
(*b*) Roads, other than carriage roads, to be used as (*a*):				
100	24			
500	10	25	20	Dwelling-houses only. Communication at one end with carriage road not less than 30 ft. wide. Fences or walls of fore-courts not to exceed 4 ft. 6 in. high. If more than 200 ft. in length a carriage road 16 ft. wide at the least to be formed at rear of houses.
(*c*) For use as secondary means of access:				
	10			

[1] London Building Acts, 1894–1908.

[2] Urban, Series IV, 1925.

In London the requirements are[1]:

	Minimum width in feet
(a) Streets for carriage traffic	40
(b) Streets for foot traffic only . . .	20

The minimum distance, in London, of a building from buildings opposite or from the opposite side of a street is 40 ft. Buildings must not, save in the case of the re-erection of old buildings, or with the consent of the county council, be erected within 20 ft. from the centre of the roadway in the case of streets for carriage traffic, or within 10 ft. from such centre in the case of streets for foot traffic only.

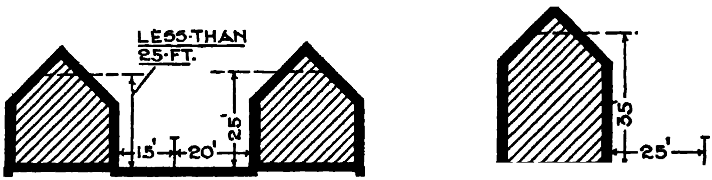


FIG. 8 FIG. 9 FIG. 10

OPEN SPACE AT REAR OF DOMESTIC BUILDINGS, AND HEIGHT OF BUILDINGS IN RELATION THERETO. MODEL BY-LAWS. FIG. 8. Building under 25 ft. in height. FIG. 9. Building 25 ft. but under 35 ft. in height. FIG. 10. Building 35 ft. and over in height.

The Model by-laws[2] specify (for domestic buildings) 24 ft., with a proviso that, where the building abuts on a street laid out before the confirmation of the by-laws and is of a less width than 24 ft., the space intervening between the building and the opposite side of the street shall equal at least the width of the street together with one-half of the difference between that width and 24 ft.

The Model by-laws require[2] that at least one end of a street shall be open from the ground upwards to the full width of street. In London every street must have two such entrances—a requirement prohibiting a cul-de-sac.

[1] London Building Acts, 1894–1908. The County Council may require a greater width in certain cases.
[2] Urban, Series IV, 1925.

Open Space at Rear of Buildings

An open space having an area of not less than 150 sq. ft. is stipulated by the Model by-laws [1] at the rear of domestic buildings [2] to be used wholly or partly for human habitation. Such space must exclusively belong to the building and extend throughout the entire width with a distance across determined by the height [3] of the rearmost wall as follows:

Height of rear wall in feet	*Depth of rear space in feet*
Under 25	15
25 and under 35	20
35 and over	25

Figs. 8 to 10 show the relationship between the height of the buildings and the depth of the open space. For sites of exceptional shape the mean depth must equal the minimum distance required.

A new building abutting on two streets may have the open space of 150 sq. ft. either at the rear or on one side, and a building re-erected in a street formed before the confirmation of the by-laws a space not less than that previously provided and in no case less than 100 sq. ft., in either instance the space to extend 10 ft. laterally, and

[1] Urban, Series IV, 1925.

[2] *Domestic building* means a dwelling-house or an office building, or other outbuilding appurtenant to another building, whether attached thereto or not, or a shop, or any other building not being a public building or of the warehouse class.

Public building means a building used or constructed or adapted to be used, either ordinarily or occasionally, as a church, chapel, or other place of public worship, or as a hospital, workhouse, college, school (not being merely a dwelling-house so used), theatre, public hall, public concert room, public ballroom, public lecture room, or public exhibition room, or as a public place of assembly for persons admitted thereto, by tickets or otherwise, or used or constructed or adapted to be used, either ordinarily or occasionally, for any other public purpose.

Building of the warehouse class means a warehouse, factory, laundry, brewery or distillery.

[3] That is, 'the height of the highest portion of the building measured upwards from the level of the ground over which the open space shall extend to the level of half the vertical height of the roof, or to the top of the parapet, whichever may be the higher'.

have a distance across of not less than 10 ft. If the open space does not abut on a street, a passage or other similar opening must be provided between so as to allow the free circulation of air in the open space. All open spaces must be without any erection above the ground level other than a water-closet, earth-closet, a privy[1] or an ashpit.

For a domestic building intended to be used as a stable the depth of the open space is not stated, but the latter must adjoin the building, belong exclusively thereto, and have a minimum aggregate extent of 150 sq. ft. For a lock-up shop an open space is required at rear or side, of not less than 60 sq. ft. with a minimum distance across of 4 ft. No provision is made by the by-laws for an open space at the rear of buildings other than 'domestic'.

The London requirements are:

(*a*) A 'domestic[2] building' erected after commencement of the principal Act[3] and having a habitable basement must have (at the basement level) an open space exclusively belonging thereto of 100 sq. ft., free from any erection above the level of the adjoining pavement. Such space need not adjoin the rear boundary of the premises.

(*b*) A building erected and abutting upon a street

[1] A privy is not permissible if the distance across the open space is only 10 ft.

[2] London Building Acts, 1894–1908. A *domestic building* includes a dwelling-house and any other building not being a public building or of the warehouse class. (*Note*: With respect to open spaces and height of buildings a 'domestic building' does not include any building used or constructed or adapted to be used wholly or principally as an office or counting-house.)

A *public building* means a building used or constructed or adapted to be used as a church, chapel, or other place of public worship, or as a school, college, or place of instruction (not being merely a dwelling-house so used), or as a hospital, workhouse, public theatre, public hall, public concert room, public ballroom, public lecture-room, public library, or public exhibition room, or as a public place of assembly or used or constructed or adapted to be used for any other public purpose, also a building used or constructed or adapted to be used as an hotel, lodging-house, home, refuge, or shelter, where such building extends to more than 250,000 cu. ft. or has sleeping accommodation for more than 100 persons.

A *building of the warehouse class* means a warehouse, factory, manufactory, brewery, or distillery, and any other building exceeding in cubical extent 150,000 cu. ft. which is neither a public building nor a domestic building.

[3] 1894.

formed after the commencement of the Act needs an open rear space of 150 sq. ft. free from any erection above the pavement level, except a water-closet, earth-closet, privy, or receptacle for ashes not exceeding 9 ft. in height. Where there is a basement story directly and sufficiently lighted and ventilated by the open space provided under (*a*), irrespective of any use to which the ground story is appropriated, or where there is no such basement story but where the ground story is not constructed or adapted to be inhabited, the open space required may be provided above the level of the ceiling of the ground story or a level of 16 ft. from the level of the adjoining pavement. The open space must extend throughout the entire width of such building to a depth in every part of at least 10 ft. from the building.

With 'domestic' buildings (other than working-class dwellings) erected after January 1st 1895 on a street formed prior to such date the open space may likewise be above the ceiling of the ground story or a level of 16 ft. above the pavement.

These requirements in respect to the provision of an open space at the rear of the building do not apply where the latter abuts on an open space of not less than 80 ft. in depth, dedicated or secured permanently for public use. The height of buildings also may be extended above the diagonal line if an equivalent open cubic space is provided to the satisfaction of the Council.

Figs. 14 and 15 show block plans of buildings with open spaces as regulated by the form of planning and intended use.

A special provision applicable to dwelling-houses for the working-class erected or adapted after 1894 and not abutting upon a street is to the effect that if the plans submitted for approval show that a sufficient open space for the admission of light and air is not provided for, such may be prescribed; but the Council cannot, however, require the provision of a greater open space than could

be required if such buildings were to be erected abutting on a street formed after the 1st January 1895. Domestic buildings (other than working-class dwellings) may be re-erected on the exact site occupied previously by similar buildings, and of the same dimensions.

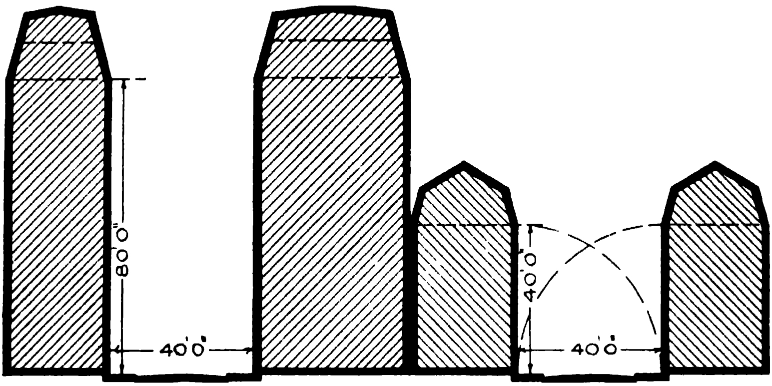


FIG. 11 FIG. 12

NON-DOMESTIC BUILDINGS—LONDON.

FIG. 11. Height of buildings on street formed before 1862. No rear space required. Roof slope of warehouse building must not exceed 47°.

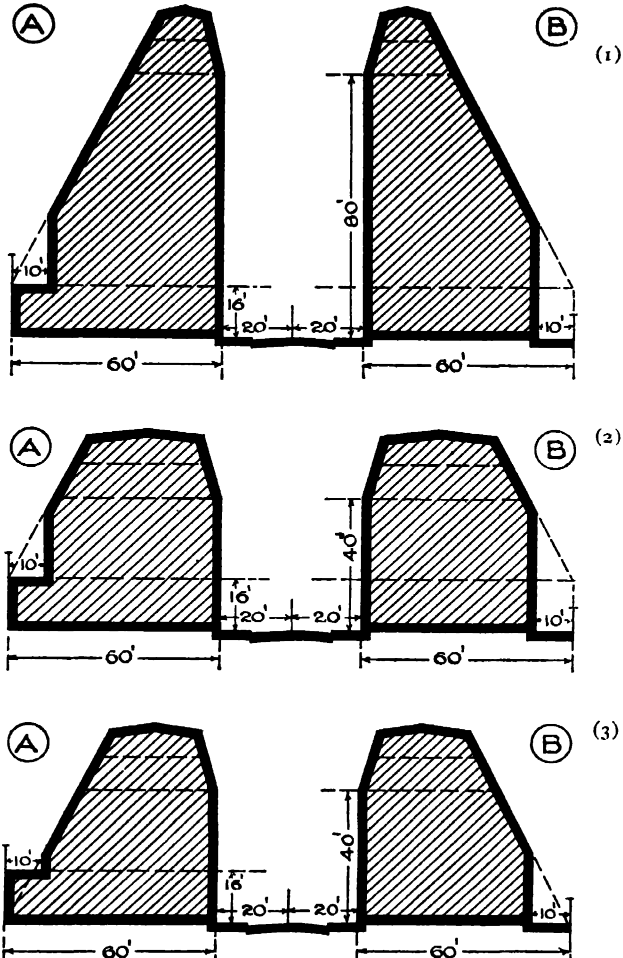
FIG. 12. Height of buildings on street formed after 1862. Height regulated by width of street where less than 50 ft. wide. No rear space required. Roof slope of warehouse building must not exceed 47°.

Buildings outside of the definition 'domestic'[1] buildings are not affected by the requirements relating to the open space at the rear, but if any building other than a domestic building contains habitable rooms the latter must conform with the provisions relating thereto.

Height of Buildings

In London a building cannot be erected to a greater height than 80 ft. (exclusive of two storys in the roof) without the consent of the County Council, and a dwelling-house for persons of the working-class[2] must not, without consent, be erected within 20 ft. of the centre of the road-way to a height exceeding the distance of the front or

[1] See note 2, p. 38. [2] See footnote on p. 123.



OPEN SPACE AT REAR OF DOMESTIC BUILDINGS AND HEIGHT OF BUILDINGS IN RELATION THERETO—LONDON.

FIG. 13. (1) Buildings on street formed before 1862. A. Rear space 16 ft. above pavement-level except for working-class dwellings. B. Rear space at pavement-level for working-class dwellings.

(2) Buildings on street formed between 1862 and 1895. A. Rear space 16 ft. above pavement-level except for working-class dwellings.' B. Rear space at pavement-level for working-class dwellings.

(3) Buildings on street formed after 1894.

A. Rear space 16 ft. above pavement-level.

(1) Where habitable basement is provided with an open space not less than 100 sq. ft., or

(2) Where no basement is provided and the ground story is not constructed to be inhabited.

B. In other cases rear space at pavement-level.

nearest external wall of such building from the opposite side of the street. Outside London there is no general provision or Model by-law controlling the height of buildings, but in some areas a private Act has been obtained for the purpose.

The limitation in London to a height of 80 ft. applies (with certain exceptions) to buildings in all streets whatever the width. In streets formed after the 7th August 1862, and of a less width than 50 ft., consent is necessary

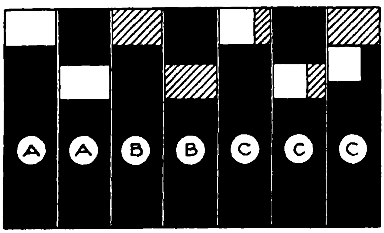


FIG. 14

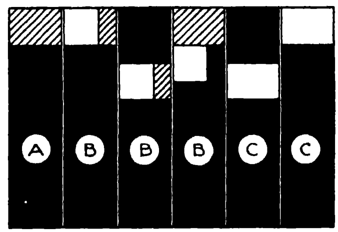


FIG. 15

FIG. 14. Block plans of new domestic buildings on street formed before 1895.

AA. Non-basement working-class dwellings with open space at pavement-level.

BB. Non-basement buildings not constructed as working-class dwellings, with open space 16 ft. above pavement-level.

CCC. Basement buildings not constructed as working-class dwellings, with open space 16 ft. above pavement-level and 100 sq. ft. of open space for lighting and ventilating basement.

FIG. 15. Block plans of new domestic buildings on street formed after 1894.

A. Non-basement building with ground story not constructed for habitation. Open space 16 ft. above pavement-level.

BBB. Basement buildings with ground story not constructed for habitation. Open space 16 ft. above pavement-level and 100 sq. ft. of open space for lighting and ventilating basement.

CC. Buildings other than A and B.

to the erection of buildings to a height exceeding the distance of the front or nearest external wall of such building from the opposite side of the street. The permissive heights are shown diagrammatically by Figs. 11, 12, and 13.

The height of a domestic building in relation to the open space required in the rear is determined by imaginary horizontal and diagonal lines fixed and ascertained as follows:

(1) *New buildings on a street laid out after 1894.* By means of a horizontal line drawn at the pavement level and a diagonal line drawn in the direction of the building at an angle of $63\frac{1}{2}^{\circ}$ and meeting the horizontal line at its intersection with the boundary—as in Fig. 13.

(2) *New buildings on a street laid out before 1895.* As for (1), except that the horizontal line may be drawn at 16 ft. above the pavement level, and the open space required (other than for dwelling-houses for the working-class) be provided above the level of the ceiling of the ground story or above the level of 16 ft.—as in Fig. 13.

Courts within a Domestic Building

In the case of a court enclosed on every side, the depth of which from the eaves or top of the parapet to the ceiling of the ground story exceeds its length or breadth, adequate provision for ventilation must be made and maintained by means of a communication between the lower end of the court and the outer air. Fig. 16 illustrates provision in the form of built-over passages at the ground level.

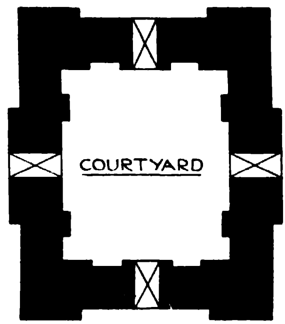


Fig. 16. Court within a domestic building showing provision for ventilation.

A habitable room[1] solely receiving its light and air from such court is not permissible unless the width of the court, as measured from the window to the opposite wall, equals half the height measured from the window-sill to the eaves or top of the parapet of the opposite wall. A court of which the greater dimension does not exceed twice the lesser dimension complies if the same

[1] This is defined as 'a room constructed or adapted to be inhabited'; while the expression 'inhabited' applied to a room means a room in which some person passes the night or which is used as a living room including a room with respect to which there is a probable presumption (until the contrary is shown) that some person passes the night therein or that it is used as a living room.' London Building Act, 1894.

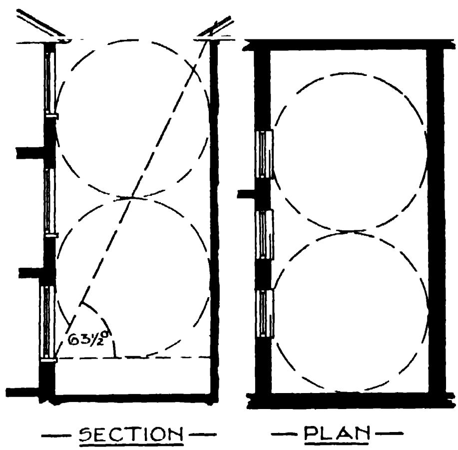


FIG. 17. Habitable room abutting on a court enclosed on every side. Minimum width of court.

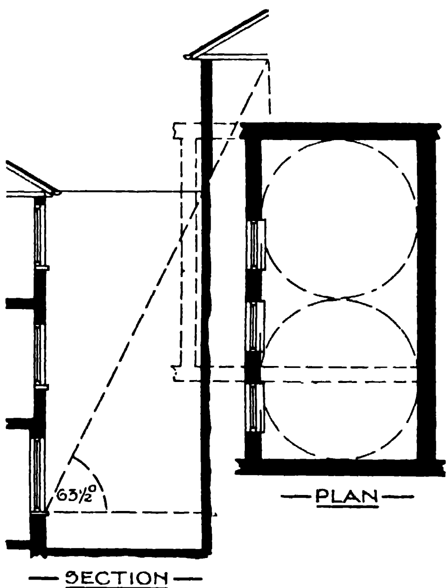


FIG. 18. Habitable room abutting on a court enclosed on every side. Minimum width of court where length is not more than twice the width.

area, but square in shape, would comply. These points are illustrated by Figs. 17 and 18.

With buildings arranged round an internal court and intended for the working-class, special provision can be required, as previously mentioned, for the admission of light and air.

With a court open on one side and having a depth measured from the open side of more than twice the width, a habitable room receiving light and air solely from the court must not be constructed above the ground story unless every window of such room is distant from the opposite wall or any other building at least half the height of the wall measured between the top of the latter and the window sill, as indicated in Fig. 19.

Back-to-back Houses

The erection of back-to-back houses intended to be used as dwellings for the working-classes is not permitted; but houses with several tenements placed back-to-back are exempt if the medical officer of health certifies that they are so constructed and arranged as to secure effective ventilation of all habitable rooms in every tenement.[1]

Legal—but Undesirable Conditions

Notwithstanding the detailed legal requirements relating to open space minima and limitation of the heights of buildings, it is an indisputable fact that such requirements often fail in securing a mode of planning buildings and an environment conducive to a good hygienic standard. Especially is this so with buildings not technically 'domestic'.

Of many undesirable features to which reference could be made attention may be drawn to—buildings several storys in height built in a continuous row or terrace without a break or opening for ventilation; long, high back-additions, with narrow intervening spaces, affecting the lighting and ventilation of overlooking rooms (Fig. 20); small, dark, central courts or well-holes—often provided for lighting and ventilating sanitary conveniences, bathrooms, and service rooms—favouring air-stagnation and commonly acting as flues supplying air to the building; and quadrangles surrounded

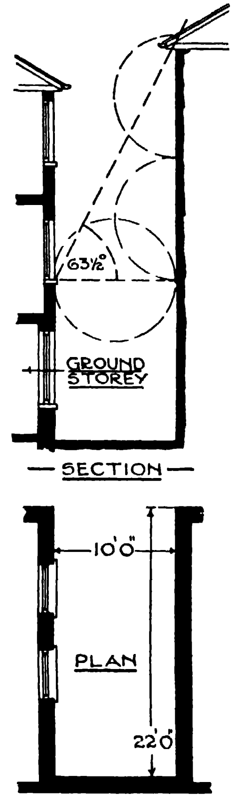


FIG. 19. Court open on one side. Minimum width of court to permit habitable room above the level of ground story.

[1] Housing Act, 1925.

by high buildings shutting out sunshine and preventing perflation; all planned and constructed so as to conform with the statute or the by-laws made thereunder, and yet obviously undesirable.

A further disability in applying statutory requirements is seen in the lack of exercisable control over the use or development of sites adjoining an existing building, and in the development of a site with regard to the surrounding conditions. For instance, a domestic building, as in Fig. 21, may be of approved height and duly provided with the necessary air space at the rear, but this space may be bounded by a high wall or building on the adjoining site which effectually darkens the rooms having windows facing the open space; or a rear space can be entirely enclosed by adjoining buildings of considerable height and thereby converted into a badly lit well with small opportunity for air-flushing.

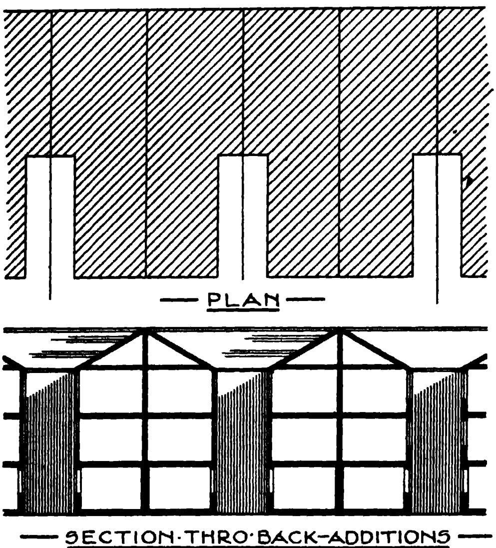


FIG. 20. Adverse effect of long and high back-additions on lighting and ventilation of rooms in adjacent buildings.

Attainment of a Healthy Environment

The ideal environment should allow an ample air-surround, free access to wind movements, and full exposure to the rays of the sun; conditions to be met only where buildings are spaced sufficiently apart, the height regulated by the intervening distances, and the orientation

such as to receive the maximum amount of sunshine. Buildings well isolated in exposed positions present no difficulty, the only *desideratum* being orientation to secure the maximum of sunshine on rooms constantly occupied, leaving the colder aspect for offices, &c. For the former a south or south-west aspect is most acceptable. A southern slope is warmer and much more desirable than one facing north. Gradual sloping sites are better than steep hill-sides, as with the latter it is sometimes necessary to cut away and regrade the surface, as in Fig. 1, so as to prevent upland surface and subsoil water draining over and soaking into the site, and to allow sufficient air space around the buildings.

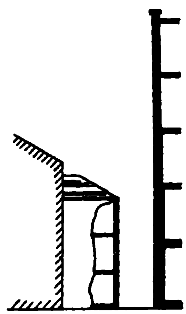


FIG. 21. Adverse effect of high building on lighting of rooms.

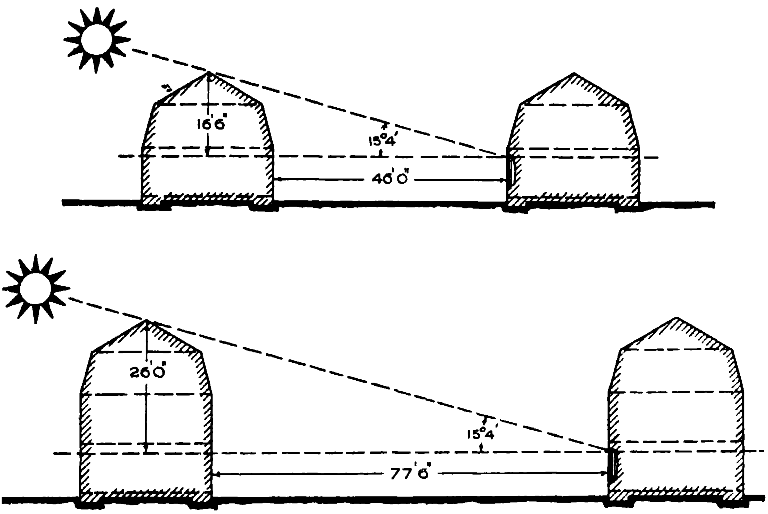
In some districts the scarcity of land is responsible for the close packing of buildings on restricted sites; but all too often tendencies to crowding are most pronounced with the development or redevelopment of areas on strictly productive lines, which course makes it compulsory to 'close-up' the buildings and thus utilize the available land to the utmost. For housing schemes, 12 houses to the acre are suggested[1] for urban and 8 to the acre for rural districts, and adherence to these standards should not, with two-story dwellings, involve any considerable difficulty in providing a sufficient light- and air-surround.

The redevelopment of cleared areas in towns is a problem of greater difficulty, especially where the aim is to rehouse at least an equivalent number of persons to those displaced. Generally, it is impracticable to effect this in the form of two-story dwellings and at the same time give adequate open spaces. Therefore, higher buildings of the 'block' type are imperative,

[1] *Manual on the preparation of State-aided Housing Schemes*, 1919. Local Government Board.

placed as far apart as needed to ensure access of light and air.

Emphasis is frequently laid unduly on the density of population on a given area as a criterion of unhealthiness. Much, however, depends upon the particular characteristics. If the case is one where buildings of many floors



DIAGRAMS SHOWING RELATION BETWEEN MINIMUM SUN ALTITUDE (AT NOON IN WINTER) AND HEIGHT AND DISTANCE APART OF BUILDINGS IN LONDON.

FIG. 22 (above). Two-story buildings. FIG. 23 (below). Three-story buildings.

are crowded together with insufficient air- and lighting-space the charge of unhealthiness doubtless can be substantiated; but with an area of old, worn-out cottage property amidst restrictive surroundings it is, to say the least, likely that an identical number of persons can be housed on the same area in buildings of greater height without any detrimental effect upon health. Fig. 3 illustrates the vast improvement possible in the case of 'cottage' areas by reconstruction on the lines of upward extension.

In deciding the height and the plotting of intervening distance between buildings intended for any class of occu-

pation, the minimum altitude of the sun at noon in winter should be regarded as the primary and essential factor, for this governs the impingement of sunshine on the walls of the building and its entrance to the interior. As a datum line the head or sill of the ground story windows or the ground line may be taken, the last-mentioned being pre-

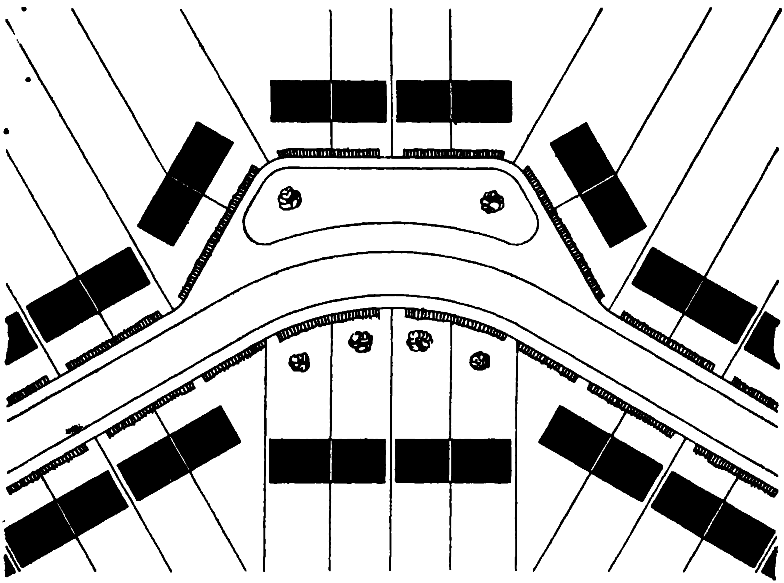


FIG. 24. Modern lay-out of buildings to ensure access of sunshine and air.

ferable as it exposes the whole of the external wall to the rays of the sun.

Taking the latitude of London as an example, the sun has its minimum altitude in December at an angle of 15°4′. Figs. 22 and 23 show the angle of incidence as it affects two-, and three-story buildings on a level site. From these illustrations it can be gleaned that to secure sun impingement the minimum intervening distances respectively required for buildings of the height given are 46 ft. and 77 ft. 6 in.

If the distance apart is a fixed point, then the height of the buildings can be determined similarly.

One of the most important phases in recent housing developments is the attention paid to the lay-out of the area, both as regards the roads and the plotting of the houses. Attention is specifically directed to an orientation that will obtain as much sunshine as possible, perflation between groups of houses, and the elimination of back-

FIG. 25. Typical City lay-out, with buildings so crowded on site as to restrict access of light and free air-movement.

additions and other projections cutting off light and interfering with air-movements. A lay-out as in Fig. 24 gives a hygienic presentment to which the grouping in Fig. 25 is a stranger, and constitutes the planning basis of a 'garden city' development deserving of general adoption. Fig. 26 represents block plans of buildings surrounding a quadrangle, with openings permitting air-movement through the enclosed space.

In addition to the notes on choice of site (see Chapter I,

p. 21) issued by the Local Government Board,[1] the following dicta are worthy of note on the questions of aspect and plotting of the houses, viz. 'The placing of the houses should be considered in reference to the sunlight, which is very rapidly obscured if the houses face one another at less distance than 70 ft. On main roads where there is much traffic it is particularly desirable that the houses should be well set back. It may sometimes be an advantage on account of the dust and noise of the road, or in order to secure a better aspect for the houses, that they should be planned mainly on short side roads; in some cases footpath access to houses set at right angles to the main road may be sufficient.'

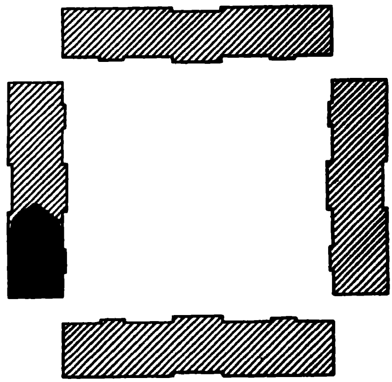


FIG. 26. Block plan of buildings in a quadrangle with provision for perflation.

As an example of a mode of plotting on a steep gradient so that the outlook is not interfered with, Fig. 1, which is based on an illustration in the Manual referred to in the footnote, is of interest.

[1] *Manual on the preparation of State-aided Housing Schemes*, 1919. Local Government Board.

III

DAMPNESS OF BUILDINGS: STATUTORY REQUIREMENTS AGAINST, AND THE CAUSATION OF DAMPNESS

THERE may be uncertainty and difference of opinion as to whether dampness in occupied buildings is the *causa vera* of specific diseases, and doubt may be thrown upon the popular belief that a damp dwelling is directly conducive to such complaints as rheumatism and catarrhs;[1] but there can be no two opinions that dampness is definitely responsible for much deterioration of wood- and plaster-work, for musty odours, and an unwholesome atmosphere within buildings, which together constitute a condition incompatible with good health.

Legislative Control of Existing Premises

The necessity of preventing and remedying dampness is recognized by statutes and by-laws authorized thereunder. So far as existing premises are concerned any in such a damp state as to be a nuisance or injurious to health can be dealt with summarily under the Public Health Act, 1875, or the Public Health (London) Act, 1891, as a nuisance; a provision explicitly extended by the Public Health Acts Amendment Act, 1907,[2] to 'any gutter, drain, shoot, stack-pipe, or down-spout of a building, which by reason of its insufficiency or its defective condition shall cause damp in such building or in an adjoining building; and any deposit of material in or on any building or land which shall cause damp in such building or in an adjoining building so as to be dangerous or injurious to health'.

[1] See Chapter I, p. 4.

[2] Not applicable to London.

A dwelling-house[1] may, by reason of its damp state, be determined as unfit for habitation within the meaning of the Housing Act, 1925. Dampness also has a bearing upon the question whether houses of a rental value not exceeding £40 (London) and £26 p.a. (elsewhere than in London) are in all respects reasonably fit for occupation.

Legislative Control of New Buildings

Form of construction.

Codes of by-laws made for the purpose of controlling the erection of new buildings include many requirements designed to attain stability and at the same time prevent dampness. The Model by-laws[2] specify that external and party walls if solid must be constructed of good whole bricks or stone properly bonded and solidly put together with good mortar compounded of good lime and clean sharp sand or other suitable materials, or with good cement mixed with clean sharp sand, or other good, hard, and suitable incombustible material properly and solidly put together.

Hollow walls may be constructed, each part to be not less than 4 in. in thickness except where the length and height respectively are limited to 25 and 20 ft., for which a minimum thickness is allowed of 3 in.; but the cavity must not exceed 3 in., and must be properly drained and ventilated. Hollow blocks are also permitted if constructed of good cement, concrete, or other material not inferior in strength and impermeability, with an aggregate thickness of 9 in., a cavity not exceeding 4 in. in width, and a minimum substance of 3 in. at the sides of any cavity.

With all hollow walls all woodwork which may be intended to form the head of a door frame, window frame, lintel, or other similar structure, and is inserted in the wall so as to project into or extend across the cavity, must

[1] For the purposes of the Housing Act, 1925, this expression includes any yard, garden, or outhouses, and appurtenances belonging thereto or usually enjoyed therewith.

[2] Urban, Series IV, 1925.

be covered throughout on the upper side with a layer of sheet lead or other suitable material impervious to moisture, in such manner as effectually to protect the woodwork from any moisture that may enter the cavity.

For domestic buildings[1] not comprising more than two storys nor exceeding 18,000 cu. ft. in capacity, special systems of construction are allowable, in all circumstances the walls to be of good and suitable materials of sufficient stability and reasonably weatherproof; provided with an effective damp course (see Chapter V, p. 81); erected on a brick or stone foundation $8\frac{1}{2}$ in. thick or other hard and suitable incombustible material of sufficient thickness properly and solidly put together to a height of 6 in. above the surface of the adjoining ground; or on sufficient piers of a like height.

Under the Housing Acts the Minister of Health has approved new systems of house construction[2] to some of which special attention is needed to prevent the incursion of damp. Approved systems embrace (1) hollow tile bricks, made of brick earth, ranging from 3 to 12-in. in thickness with skins and webs 1 in. thick and with or without concrete filling, (2) half-brick walls with 3-in. concrete slabs inside, and a 3-in. cavity between, (3) concrete bricks and slabs of various materials and a thickness of 2 in. and upwards, (4) blocks made with a cement skin 1 in. thick with an inner core of straw or other fibrous material, (5) 6-in. concrete walling poured *in situ*, with a vertical sheeting or poured damp course of bitumen in the centre, (6) $1\frac{1}{4}$-in. centre slabs of tar pitch, sand, &c., with casings of concrete, (7) asbestos cement sheet casings with the interspace filled with concrete, (8) various forms of reinforced concrete, (9) steel frame structures with an outside covering of metal lathing encased in $\frac{3}{4}$ in. of concrete and an inner shell of clinker concrete slabs, or with two sheaths of metal lathing coated with $1\frac{1}{2}$ to 2 in. of fine

[1] See definition in footnote on p. 37.

[2] See *Particulars of Systems of House Construction approved up to April,* 1920. Ministry of Health.

cement concrete, the outside concrete being applied by means of a cement gun, (10) timber framings covered with expanded metal with ¾ and 1½ in. of cement respectively on the inside and outside, (11) timber framings filled in with concrete and faced with broken flints, stone or rough-cast, with lath and plaster finish inside, and (12) timber framing finished with lath and plaster inside and outside.

Horizontal and vertical damp courses are insisted upon by the Model by-laws[1]:

'Every person who shall erect a new public building or a new domestic building shall cause every wall (including any pier forming part of a wall) of such building to have an effective damp-proof course of sheet lead, asphalte, or vitrified stoneware, or a double course of impervious slates or blue bricks laid to break joint and bedded in cement mortar, or of other not less durable material impervious to moisture, beneath the level of the lowest timbers and in the case of a solid floor not higher than the upper surface of the concrete or other similar solid material forming the structure of the floor and in any case at a height of not less than 6 in. above the surface of the ground adjoining such wall or pier.'

Further:

'Where any part of a floor of the lowest story of such building, not being a cellar adapted or intended to be used for storage purposes only, shall be intended to be below the level of the surface of the ground immediately adjoining the exterior of such story, and so that the ground will be in contact with the exterior of any wall, he shall cause such story, or such part thereof as will be so in in contact to be constructed with walls impervious to moisture or with hollow walls, constructed in accordance with the requirements of the by-law in that behalf (see p. 53), and extending from the base of such walls to a height of 6 in. at least above the surface of the ground immediately adjoining the exterior of such story; he shall also cause an effective damp-proof course of sheet lead, asphalte, or vitrified stoneware, or a double course of impervious slates or blue bricks laid to break joint and bedded in cement mortar, or of other not less durable material impervious to moisture, to be inserted in every such wall at the base of such wall

[1] Urban, Series IV, 1925.

and likewise at a height of 6 in. above the surface of the ground immediately adjoining.'

Parapet walls must be protected against the soakage of rain, the requirement being:

'Every person who shall erect a new building shall cause every wall of the building, when carried up above any roof, flat, or gutter, so as to form a parapet, to be properly coped or otherwise protected, in order to prevent water running down the sides of the parapet, or soaking into any walls.'

Roofs must be covered:

'Every person who shall erect a new building shall cause the roof, including any turret, dormer, lantern-light, skylight, or other erection forming part of the roof, to be externally covered with slates, tiles, metal or other incombustible material';

with the proviso that with houses built on a special system (p. 54) the roof may be covered with fire-resisting in place of incombustible material.

It may be noted that although the principal *raison d'être* for roof coverings is to keep out atmospheric moisture, no reference is made to the necessity for *impervious* coverings.

Roof drainage and means for conveying water away so as to prevent dampness are provided for:

'The roof of the building (whether flat or otherwise) shall be so constructed as effectually to drain to suitable and sufficient gutters, shoots, or troughs, which shall be provided for the purpose of receiving and conveying all water which may fall on the roof, and shall be connected with a sufficient number of suitable down-pipes or trunks constructed so as to carry away all such water without causing dampness in any part of any wall or foundation of any building.'

Floor ventilation is prescribed for in the words:

'Every person who shall erect a new domestic building shall so construct the whole of the floor in the lowest story of such building, if such floor be a boarded floor, that there shall be for the purpose of ventilation between the underside of every joist on which the floor is laid and the upper surface of the asphalte or

concrete with which, in pursuance of the by-law in that behalf, the ground surface or site of such building may be covered, a clear space of 3 in. at the least in every part, and he shall cause such space to be thoroughly ventilated by means of suitable and sufficient air-bricks, or by some other effectual method: Provided that the foregoing requirement shall not apply to any part of the lowest story which is provided with a solid floor composed of boards, planks or wood blocks, laid or bedded directly upon concrete or other similar dry and impervious foundation, but if he shall construct the floor in the lowest story partly in accordance with the first paragraph of this by-law and partly in accordance with this proviso, he shall so construct that part of the floor which is solid that there shall be an air channel through the concrete or other foundation.'

The requirements of the London Building Acts[1] are, in many respects, similar.

In other than concrete buildings walls must be of stone, or good, hard, sound, well-burnt bricks. Hollow walls are allowed provided the wall on one side of the hollow space is of the full thickness required by the Act. A horizontal damp course composed of materials impervious to moisture must be provided not less than 6 in. below the level of the lowest floor; and every external wall or inclosing wall of habitable rooms or their appurtenances or cellars which abuts against the earth protected by materials impervious to moisture; the materials for damp courses and the work to be subject to the approval of the District Surveyor. In a dwelling-house, floor ventilation is stipulated for every basement room having a wooden floor other than a floor constructed of solid wood bedded on concrete, with sufficient air space between the ground and the floor surface to admit of ventilation by air-bricks or otherwise.

Every party and parapet wall must be finished with one course of hard, well-burnt bricks set on edge in cement or by a coping of waterproofed material properly secured;

[1] 1894–1908.

and concrete party walls and chimney stacks carried above the roofs of buildings rendered externally with Portland cement.

Roof coverings are specified as slates, tiles, metal, or other incombustible materials; and gutters and pipes must be fixed to roofs so as to prevent water dropping upon or running over any public way.

Penetrability of Bricks, Stone, and Concrete by Moisture

Brick, stone, and concrete, while acceptable materials from the standpoint of strength, are frequently lacking in the property of impenetrability to moisture. In places where the atmosphere is charged with moisture from sea or river, and in exposed positions subject to prevailing winds carrying much rain, moisture is often absorbed into and passed through solid walls constructed of the named materials either owing to their porosity, or where non-porous, along the joints—a condition particularly observable with thin walls (9 to 14 in.) built in lime mortar with doubtful joints of the 'buttered' kind. Walls built on or in the ground are likewise subject to the absorption of damp from underlying or abutting soil.

In such circumstances where the supply of atmospheric moisture is unlimited no amount of heat inside the building will effectually dry its walls or maintain the interior in a dry state. The converse is often the case, for a high temperature within a building enables the atmospheric content to take up more moisture—a process which facilitates the passage of moisture from without to within the building.

To avoid the penetration of damp so noticeable with solid walls, hollow or cavity walls have been and are still strongly advocated. Many of the types already referred to as having received the imprimatur of the Minister of Health are constructed with this intention. It is, however, a mistaken idea to think that a hollow wall, by reason of the

existence of a cavity, prevents the passage of moisture from the outer air to the atmosphere within the building, for, unless the outer shell is impervious, moisture will pass through, be taken up by the air in the cavity and absorbed by the inner shell and thus find a way into the building, a progress which may, as before mentioned, be facilitated by the warmer air inside the building and its greater capacity for taking up hygroscopic moisture.

In the words of one authority,[1] above-ground walls of this type may afford a temporary check against rain driven by a high wind passing through, but are absolutely inefficient as a protection against damp of condensation. Protection is only temporary, because when the wall becomes soaked the air that fills the space is saturated by contact and deposits its moisture on the coldest portions of the inner leaf that is supposed to be protected. Accepting this transmission of moisture through both solid and cavity walls as a fact, the deduction is permissible that the risk is correspondingly increased where the walls are constructed of thin tiles, concrete slabs, and other like materials on certain of the systems set out above. A further point is that the ties used for bonding the inner and outer leaves together are often responsible for the transmission of moisture.

Steps to be taken for the prevention of dampness can be summed up as (*a*) the use of non-porous materials, and (*b*) watertight methods of construction; a summary that is concise, but the fulfilment of which involves much care and the consideration of many details.

Before referring to the relative porosity of building materials attention may be directed to the means whereby moisture is conveyed through seemingly solid substances such as bricks, stone, and concrete.

Dampness due to Gravity and Capillary Action

Water may be hygroscopic, i.e. water vapour contained in the atmosphere, or in a visible liquid form.

[1] *Prevention of Dampness of Buildings*, A. Knapen, M.Soc.C.E. (France).

Hygroscopic moisture takes on visibility when the dew-point is so lowered that the vapour condenses in the form of droplets of water. This conversion is most noticeable when the percentage of atmospheric humidity is high and the air is brought into contact with cooler surfaces or substances having a low specific heat. If these are pervious moisture is absorbed into the substance and possibly is unnoticed, but if impervious as, for instance, with walls painted, cement faced (particularly when trowelled smooth), or lined with glazed bricks or tiles, moisture is often deposited on the surface to the extent of running down the walls in streams and forming small pools on the floor.

This water of condensation is said to be hygienically dangerous, as it deposits ammoniacal gaseous by-products on the walls, which form a culture for all sorts of bacteria.[1]

Whether deposited from the atmosphere as just described, or as rain or snow, the absorption of water into a solid is effected either by gravity or by capillary or osmotic action, the degree of absorption being regulated by the porosity of the solid. Water falling as rain on a horizontal solid surface descends or soaks below the surface by the force of gravity, and, *per contra*, water underlying a solid ascends by the force known as capillary action or attraction; always provided the solid is not impervious.

The force of gravity thus displayed is so well understood that description is needless. Capillary action is also familiar to most, for it is seen readily in the travel of ink through blotting paper, the rise of oil in the wick of a lighted lamp, and the upward movement of moisture through the mass of a soft brick standing on wet sand or soil or partially immersed in water. This ascent of water is due to the pressure or pull of the surface tension of the liquid on the particles forming the solid with which it is in contact. In the case of a capillary tube the pressure or pull resolves itself into an attraction whereby water

[1] *Prevention of Dampness of Buildings*, A. Knapen, M.Soc.C.E. (France).

rises in the tube. The same force brings about distribution of liquid through a solid horizontally, or in any other direction, by transmission from the wetter to the drier particles.

The usual demonstration of capillarity takes the form of noting the height to which water will rise in narrow tubes; a capillary tube, i.e. a tube pertaining to a hair, giving its name to the action. The height to which water is raised in such tubes is controlled by their diameter, the smaller the tube the greater the height, the latter, in fact, being inversely proportional to the area. Thus[1]:

In a tube	1 in.	in diameter	the water	rises	0·054 in.
do	0·1 in.	do		do	0·545 in.
do	0·01 in.	do		do	5·456 in.
do	0·001 in.	do		do	54·56 in.

When the water column reaches such a height that the attraction of gravity balances the attraction of the solid forming the tube, whatever the structure of the latter, the rise of water ceases; a movement that is, however, modified in the case of buildings by aspect and local heating influences, for in walls the rise may be subject to the evaporative influence of a warm atmosphere, the damp surface being restricted to an area sufficient to effect the evaporation of the water rising each day by capillary attraction.

From the foregoing it may be inferred that the height to which water will rise in a solid depends primarily upon the texture, or the size and closeness or packing of the component particles. With coarse materials, as gravel, the interspaces are so large as practically to inhibit capillary action; whereas with fine sands and loams the action is well defined. King[2] found that a clay loam and a very fine sand respectively lifted water through 4 ft. at a rate of 0·9 and 0·91 lb. per sq. ft. in twenty-four hours. Materials such as bricks, stones, and concrete do not possess passages in the exact form of tubes, but, never-

[1] *The Soil*, p. 138. F. H. King. [2] *Ibid.*, p. 141.

theless, as with sand though more restricted, many minute cavities or interspaces exist which act as capillary tubes and enable water to rise, maybe in an irregular vertical movement, through the mass.

With buildings the absorption of water into the materials forming the structure is evidenced in many ways. Wind- and rain-pressure force water into horizontal and vertical surfaces and gravitative action continues the downward movement from, for instance, the tops of walls, chimney stacks, &c., to below the ceiling line of the upper rooms; capillary action sets up vertical movements from the soil immediately underlying brick, stone, and concrete walls to a height of several feet above the ground level; while horizontal distribution from rain-exposed surfaces or abutting soil takes place from the outside to the inside of external walls. If dampness is to be prevented the necessity of using materials and methods unfavourable to movement of water by either gravity or capillary action is therefore obvious.

IV

DAMPNESS OF BUILDINGS: POROSITY OF MATERIALS AND METHODS OF WATER-PROOFING

THE POROSITY OF MATERIALS

A PRIMARY essential of all building materials intended for external positions, that is to say, all positions subject to soil and weather, is impenetrability to moisture; compliance or non-compliance with this property in no small measure determines their relative fitness for specified duties. In the following notes their suitability is regarded solely from this aspect.

Materials having a hard, smooth surface favour surface condensation and consequently are not the most suitable for interior work. On the other hand, as they absorb much less moisture than those with a soft granulated surface they are eminently suited for exterior facings. With many impervious-surfaced materials the risk of moisture penetration is restricted to the jointing material and the method of jointing. Of such may be quoted, as a natural material, hard granite, and, as a made-up material, salt-glazed bricks and bricks faced with porcelain or vitreous enamel.

Of the materials commonly used for the exterior of buildings, lead, copper, zinc, iron, and glass may be classed as impenetrable by moisture.

Stones

The durability and weathering property of building materials depend largely upon the relationship existing between their constituents and the chemical constitution of the air. This is particularly noticeable in the case of stones. Pure country air will affect some stones. The smoky air of towns containing sulphuric, carbonic, and

hydrochloric acids, and possibly traces of nitric acid,[1] decomposes stones containing much carbonate of lime or carbonate of magnesia—such as sandstones and limestones. Such acids are taken up by the rain and atmospheric moisture and conveyed into the pores of the stone by rain-pressure and capillary action.

This atmospheric decomposition or destruction is of much importance. Certain varieties of stone—notably the Bath stones—as they come from the quarry are soft and absorbent, but become hardened on subjection to the atmosphere. Should the latter, however, be so chemically charged as to bring about surface deterioration, a free opportunity is afforded for the absorption of moisture into the surface and thence into the mass. Dampness, however conveyed, is either directly or indirectly the paramount cause of decay, and therefore its exclusion is of the utmost importance, whether consideration is given to the question from the standpoint of the passage of moisture through the material to the interior of the building, or solely on account of its durability.

A great diversity is shown in respect of the absorption of water. Marble, trap or greenstone, and basalt are practically non-porous, the absorption rarely reaching 1 per cent. of the dry weight. Sandstones variously absorb from 2 to 9 per cent., very hard substances, as 'Silex' York stone, taking up as little as 1·02 per cent. Limestones also show considerable disparity, commonly ranging from 1 to 13 per cent. Tests made of nine 4-in. cubes of Bath stone from Monk's Park Quarry gave an average absorption after 24 hours' immersion of 8·79 per cent. of the dry weight; the range being from 7·06 to 9·49 per cent.[2] Artificial stone is variable, the water absorbed depending upon the aggregate and the cementing sub-

[1] Dr. Angus Smith's researches showed that some 15,000 tons of carbonic acid were daily evolved in Manchester; the air contained 0·03 to 0·08 per cent. of carbonic acid; the rain averaged 2·9 grains of sulphuric acid per gallon, and 0·628 grains of hydrochloric acid.—*Air and Rain*.

[2] *Vide* tests made by Messrs. David Kirkaldy & Son for the Bath Stone Firms, Ltd.

stance; good varieties show an absorption varying from 2 to 7 per cent. of the dry weight. If waterproofed cement is employed artificial stone is practically non-porous.

Stones which absorb more than 10 per cent. of their dry weight during an immersion test of 24 hours cannot be regarded as satisfactory for external positions.

Bricks

Extreme divergencies are seen in the amount of water taken up. Grizzles and place bricks are soft and absorb a large quantity; so do rubbers and many first-quality red facing bricks; while hard bricks of the Staffordshire type are almost non-absorptive. Soft and insufficiently burnt bricks will take up more than 20 per cent. of their dry weight.

The following table shows the porosity of varieties of bricks as disclosed by special tests:

TABLE NO. I.[1] *Showing the relative porosity of various bricks as determined by a comparison of the dry weight with the weight after twenty-four hours' immersion.*

Name or description of brick.	*Weight—dry (in grams).*[2]	*Weight—wet (in grams) after 24 hours' immersion.*	*Percentage porosity (increase in weight).*
	Blue Staffordshire Bricks.		
Blue Pressed	4,000	4,040	1·0
Blue Wire-cut	3,870	3,900	0·07
Blue 2 Panel	3,770	3,780	0·031
Blue Wire-cut	3,970	4,050	2·01
Blue $9 \times 4\frac{1}{4} \times 2\frac{1}{2}$	3,550	3,600	1·3
Blue $9 \times 4\frac{1}{4} \times 2\frac{1}{2}$	3,650	3,750	2·7
	Engineering Bricks.		
Engineering Red	3,200	3,380	5·6
"	3,480	3,490	0·28
"	3,390	3,490	2·9
"	4,220	4,470	5·9

[1] These tests were carried out in the Building Laboratory of the Polytechnic, Regent Street, London, School of Architecture, Building, and Surveying, under the direction of Mr. George A. Mitchell, F.R.I.B.A., Head of the Department, and Mr. A. E. Holbrow, A.R.I.B.A., Lecturer on Building Materials, to whom the Author is indebted for the particulars.

[2] 28·3496 grams = 1 oz. and 453·593 grams = 1 lb.

Name or description of brick.	*Weight—dry (in grams).*	*Weight—wet (in grams) after 24 hours' immersion.*	*Percentage porosity (increase in weight).*
	Fletton Bricks.		
Fletton Brick	2,370	2,750	11·3
,, (4 press)	2,550	3,000	18·5
,, ,,	2,500	2,930	17·2
,, ,,	2,520	3,100	23·2
Multi-coloured Ruff	2,790	3,220	15·4
$2\frac{5}{8}''$ Best Facing	2,600	3,190	22·6
Best White	2,530	3,080	21·3
Hand-made Sand Faced	2,320	2,600	12·1
,,	2,270	2,550	12·3
,,	2,360	2,600	10·2
,,	2,210	2,500	13·1
,,	2,320	2,660	14·7
Glazed Facing Brick	3,150	3,500	11·1
Hand-made Sand Faced Red	2,910	3,350	15·1
Rustic Wire-cut Facing	3,370	3,900	15·8
Grey Facing Brick	2,880	3,200	11·1
2″ Purple Kiln	1,980	2,150	8·4
2″ Flared Red	2,220	2,330	4·9
2″ Medium Kiln	1,970	2,130	8·1
Flared Red	2,960	3,080	4·06
Sand Faced	2,840	3,000	5·6
Rubber Brick	3,980	4,580	15·1
,,	4,020	4,580	13·6
Lingfield Pressed	3,650	3,800	4·1
Mottle Pressed Facing Brick	3,390	3,420	0·8
Wire-cut Brindle $2\frac{5}{8}''$ side	4,000	4,980	25·5
	London Stocks.		
London Stock	2,300	2,670	16·08
,,	2,360	2,570	8 8
,,	2,250	2,510	11·5
,,	1,880	2,150	14·3
,,	2,210	2,460	11·3
,,	2,250	2,440	8·4
,,	2,000	2,220	11·0
,,	2,300	2,440	6·08
	Paving Bricks.		
2″ Brindle Pavior	2,780	2,790	0·35
Red Pressed Pavior	2,760	2,770	0·36
	Fireplace Bricks.		
Fireplace Brick	820	940	14·7
,,	680	760	11·7
Kerb brick	490	560	14·2
	Coke Breeze Brick.		
Coke Breeze Brick	2,300	2,620	14·08

Sand-lime bricks are made from silicious quarry, pit, or river sand, or from refractory and waste materials or by-products such as slag, clinker, shale, quarry-waste, shards, &c., mixed with 'fat' or hydraulic lime in proportions varying from 5 to 10 per cent. of the sand, pressed, and hardened by exposure to steam at a pressure of not less than 100 lb. per sq. in. in closed cylinders for 8 to 10 hours.

According to the Building Research Board[1] bricks not of the highest class 'must not be used for damp situations, or below the damp course in any situation; they rapidly deteriorate to the condition of bad old lime mortar. On the other hand, the life of good sand-lime bricks, i.e. those in which the sand has combined with the highest possible proportion of lime to form calcium silicate, may be put as equal to the life of good sandstone; and especially it has been found that they improve with age in damp situations.'

For sand-lime (calcium-silicate) bricks the B.E.S.S.[2] test for absorption provides that: At least 5 dried bricks should be weighed and submerged in water at a temperature of from 60° F. to 80° F. (15·6° C. to 26·7° C.). The water containing the bricks should be raised to boiling point within 1 hour and kept boiling continuously for 5 hours and then allowed to cool down to 60° F. or 80°F. The bricks should then be removed, wiped clean, and weighed. The percentage increase in weight of each brick by absorption of water should not exceed:

For Class A (Engineering Bricks)	10 per cent.
For Class B (Bricks for external walls)	

A test applied to 3 sand-lime bricks (grey) made from dredged sea sand and high calcium lime disclosed after 24 hours' immersion an added weight due to absorption respectively of 14·8, 12·9, and 7·1 per cent. of the dry weight; and to 3 made from pit sand (containing 10 per

[1] Special Report No. 1, *Sand-Lime and other Concrete Bricks*, 1921.

[2] British Engineering Standards Association, Specification No. 187, 1923.

cent. impurities) and dolomitic lime respectively 9·44, 9·29, and 7·3 per cent. of the dry weight.

Cement concrete bricks vary enormously in porosity by reason of the difference in the character of the aggregate, the proportion of cement used, and the method of manufacture.

In the making, the conclusions of the Building Research Board[1] are of great value, viz.

'The best aggregate is a sharp, clean, pit or river sand; but any aggregate that is used for ordinary cement concrete may be used, so long as it is not too coarse. Excellent bricks can be made of quarry waste, broken brick, furnace clinker, ashes, broken chalk, with those proportions of cement which are found suitable after experiment. The aggregate must be well graded; except when it is so soft that it breaks down partially when tamped, and all voids are, incidentally, filled. So-called "coke breeze" and "clinker" should be tested for unburnt coal. Destructor ash may contain salts which will cause efflorescence.

'Portland Cement to the British Engineering Standard Specification should be used where procurable, but for work exposed to sea-water a slag-cement may be preferable. True "Iron Portland Cement" may be used with confidence as a substitute for Portland Cement. . . .

'The Cement proportion should not ordinarily fall below 6 of the aggregate to 1 of Portland Cement where the bricks are hand-made, or 9 to 1 where they are power-tamped. But a 12 to 1 mixture has given good results with chalk as aggregate, and it may be stated as a general principle that the better graded the aggregate the smaller is the proportion of cement necessary.

'It is not too much to say that there is nothing more generally durable than good cement concrete. Its many good and few bad points are too well known to need description; they should not be forgotten, however, as advantage may be taken, where the extra expense is justified, to modify the concrete to suit special circumstances. For instance, where a hard-wearing surface is required, the bricks may be built up in the moulds with a face of granite chips, or other vitreous aggregate. . . . For integral waterproofing an 8 per cent. solution of potash soap ("soft soap") may be used

[1] Special Report No. 1, *Sand-Lime and other Concrete Bricks*, 1921.

as the mixing water; this develops an alum soap in the body of the concrete, and is better than using a proprietary article of indefinite composition. A solution of silicate of soda ("water-glass") may be used for the same purpose. The use of any oil or organic material . . . should be avoided. . . .

'In general it may be said that although some proprietary articles are not without virtue, they should be avoided unless their composition is known, not forgetting that it is usually possible to make up similar material at a lower cost. The extensive advertisement of a substance under a striking name does not in any way reinforce its properties.'

Porosity Not the Sole Determinant of Fitness

The amount of water which a brick will absorb is a fair indication of its quality, but does not necessarily show either its weathering property or its resistance against the absorption of moisture *in situ*, as these may depend more upon the character of the surfaces exposed to moisture than upon the nature of the mass. As an example, a face-glazed brick when steeped in water may disclose a large dry weight percentage absorption, and for this reason would be quite unsuited for positions where water could be absorbed into the unglazed surfaces, and yet such a brick would weather well when laid so that only the glazed surface is exposed.

Bricks which absorb on immersion in water for 24 hours more than 10 per cent. of the dry weight cannot be considered suitable for exterior work. Bricks intended for damp-proof courses should be highly vitrified and the porosity should not exceed 1 per cent. of the dry weight, a standard (excepting salt-glazed and other similar bricks) only attained by bricks of the blue Staffordshire variety, in which the porosity is negligible.

Terra-cotta

If made from suitable clays with the addition of substances—such as ground glass and pottery—to obviate shrinkage, and properly burnt, terra-cotta is non-porous so

far as the surfaces are concerned; but if the latter are chipped or scaled, water is readily absorbed, and especially so if fireclay is used in the manufacture.

WALLS: CHOICE OF MATERIALS

For the reasons previously given the non-absorptive or water-repelling qualities of materials for walls should in no small measure control their selection. To a marked extent materials which have a low porosity also weather well and provide the strength requisite for sound construction.

Concrete and Mortar

Concrete may be classified under three heads, (1) cement ballast, (2) cement breeze, and (3) lime.

Cement concrete composed of ballast, gravel, broken brick or stone, or furnace clinkers with clean sharp sand in the proportions of, say, one of Portland cement, two of sand, and three of coarse material,[1] is porous and will not resist capillary action when exposed to rain or wet-soil conditions, although if smoothed on the surface it is sufficiently non-porous to allow of the deposition and retention on the surface of moisture from saturated air.

If good cement concrete as just described is porous it may be inferred that cement concrete composed of coke breeze in the proportions of, say, one part Portland cement to five parts of properly burned and clean coke breeze of $\frac{3}{4}$- or $1\frac{1}{2}$-in. grading (a composition accepted for good-class work) which greedily absorbs water, must be regarded as unsuitable for external positions unless properly rendered with cement or otherwise satisfactorily surfaced.

Cement concrete, whatever the gauging or strength, must be regarded as porous, the degree of porosity turning upon the character of the aggregate, the quality and proportion of cement, and the quantity of water used in the mix. It may vary from 1 to 30 per cent. of the dry weight. With regard to the passage or leakage of water through

[1] As specified for walls in the by-laws made by the London County Council under s. 16 of the Metropolis Management and Building Acts Amendment Act, 1878.

the mass, as distinct from absorption, the occurrence of cracks cannot be disregarded.

Lime concrete containing a mixture of various substances to form an aggregate, with grey, blue lias or other hydraulic lime as a matrix, is little better than brick rubbish or hard-core in a damp situation, as it does not set properly. In no circumstances can it be accepted as an effective damp resister.

Lime mortar composed of freshly burned lime and clean sharp sand or grit without earthy matter in the proportions of one of lime to three of sand or grit[1] is highly absorptive.

Cement mortar consisting of Portland cement and clean sharp sand or grit in the proportions of one of cement to four of sand or grit, as used for walling, and mortar gauged one of cement to two of sand, as used for rendering, is classifiable as porous. A trowelled finish to cement renderings closes the surface pores and thus reduces the opportunities for absorption.

Slates

Good quality slates are practically impervious to moisture. The increase in weight of dry slate after immersion in water for 24 hours should not exceed 1 per cent. Resistance to capillarity may be judged by standing a thoroughly dried roofing slate on edge in water to half its height. So placed a good slate should not show after 12 hours' immersion any sign of moisture above the waterline.

Tiles

Tiles made from brick-earth are more porous than slates, and unless made of good clay and well vitrified will absorb sufficient moisture to communicate dampness to the supporting timbers.

Many differences are seen in the porosity even with tiles of the same make. The percentage increase in the dry weight after 24 hours immersion in water will range

[1] See footnote on p. 70.

from 6 to 10 per cent. in well-vitrified tiles of good brick earth to as much as 20 per cent. in the case of poorly-burnt tiles made from unsuitable clay. Tiles having a porosity in excess of 10 per cent. of the dry weight should be regarded as unsuitable.

Asbestos Cement Slates or Tiles, and Sheets

The Standard British manufacturing practice provides for $87\frac{1}{2}$ per cent. cement and $12\frac{1}{2}$ per cent. asbestos fibre. The fibre varies enormously in quality and the asbestos cement product of different manufactures may vary in strength to the extent of 100 per cent. The proper method of manufacture is to build up the sheet by compression in a roller mill—a $\frac{3}{16}$ in. thickness consisting of some 24 layers. Sheets made from asbestos powder, or mould pressed, should be taboo as they constitute a low-grade product. The porosity varies considerably. The author found that of six sample slates from two of the best makers, on immersion in water for 24 hours, two showed no difference between the dry and wet weights, and four an increase of wet weight over dry of 8·3, 12·5, 12·5, and 15·4 per cent.

Poor quality asbestos cement is liable to become porous on exposure to the weather.

Wood

In this climate the wood which, in its natural state, will most reasonably withstand atmospheric influences is oak. For above-ground positions where not in contact with the soil it may be used without special treatment. Most woods are rapidly affected by moisture and where fixed externally or influenced by soil dampness are much subject to wet rot, particularly when the temperature ranges around 60° F.

Damp-proof Construction

With an acknowledgement of the fact that the materials used often inherently lack resistance to dampness the

problem of securing a damp-proof building may be considered in order as (1) the waterproofing of the materials prior to or during incorporation in the building; (2) the adoption of damp-resisting constructional methods, and (3) damp-proofing of the materials *in situ.*

Waterproofing Materials

Marked attention has of late been focused upon the use of substances and methods for converting inherently porous building materials into non-porous materials. This is partly the outcome of a fuller recognition that a damp building is an unhealthy building, and partly the necessity of finding new forms of construction and the use of new or unusual materials to cope with building needs. From the latter aspect the increasing use of concrete and the official approval of materials in new forms, to which attention is drawn in Chapter III, p. 54, have been important factors calling for the adoption of some method of waterproofing.

Cement mortar and concrete. These mixtures may be waterproofed by using a waterproofed cement or by adding to Standard Portland Cement[1] a waterproofing medium in powder or liquid form. Well-known waterproofed cements are 'Super Cement' and 'Dampro'. Of the many admixtures obtainable the following may be mentioned:

Dry mix	*Liquid mix*	
'Ironite'	'Castor'	'Colemanoid'
'Pudlo'	'Cementfortis'	'Prufit'
'Toxement'	'Ceresit'	'Semplax'

Waterproofing substances intended for admixture with cement mostly fill up the voids or intermolecular spaces with a fine, elastic, insoluble matrix in colloidal (i.e. glue or jelly) form, thereby preventing penetration of moisture by capillarity or under pressure. Certain of the substances have as a base a mixture of calcium chloride and china clay.

[1] British Engineering Standards Association, Specification No. 12, 1925.

Various and wide claims are put forward on behalf of these patent substances, and doubtless such claims can be substantiated if regard is had to their application for the stated purposes in the manner specified by the manufacturers. Herein lies the difficulty. As an illustration may be cited two classes of vertical damp-proofing, (1) asphalting, and (2) rendering with waterproofed cement. The first class of work is almost always undertaken by specialist workmen sent out by the firm supplying the materials, and consequently is carried out in the best manner for securing the desired results. In the second class of work the waterproofing substance is supplied to a builder and the work is done by an employee who may not be expert in the use of the substance and who frequently pays far too little attention to the manufacturer's instructions, with the result that failure ensues instead of the success which should be met with by a proper application.

Much therefore may be said in favour of using a substance which does not necessitate any special precautions or safeguards, and consequently a cement, waterproof in itself and the use of which in preparing either mortar or concrete is easily understood and controlled (inasmuch as it is solely regulated by gaugings as commonly followed), must obviously be regarded as the best medium to employ.

The stone aggregate for the concrete should consist of particles of broken stone, preferably of a silicious nature, or of sound hard granite, free from disintegrated rock, fine clayey dust, loam or other harmful vegetable or mineral matter. The grading of the particles from coarse to fine should be approximately uniform. For mass concrete the grading should range from a maximum size passing a screen having 1½-in. diameter holes to a minimum size retained upon a sieve having 4 meshes per linear inch. For reinforced concrete the aggregate should vary from a size passing a 1-in. screen to the minimum size above described. Broken granite or hard stone should contain

not over 5 per cent. by weight of clean crusher dust: gravel, not over 5 per cent. by weight of sand aggregate (material passing a sieve having 4 meshes per linear inch) and free from mineral or other coatings.

The sand aggregate for concrete should consist of hard, tough, preferably silicious material, clean and free from mineral or other coatings, lumps, soft particles, clayey dust, 'clay balls', loam or other harmful vegetable or mineral matter. The particles should be well graded from a size that will pass a sieve having 4 meshes per linear inch to a size retained upon a sieve having 100 meshes per linear inch. Not more than 25 per cent. and not less than 15 per cent. should pass a sieve having 50 meshes per linear inch.

Sand should not contain more than 5 per cent. by weight of sandy dust (material passing a 100-mesh sieve) and not more than 3 per cent. by weight should be removable by washing.

Water containing vegetable or other organic matter is at all times injurious. Alkaline waters, more especially those containing magnesium and sodium sulphates, will attack the cement chemically and have been found to possess a strong disintegrating effect. Waters from manufacturing plants frequently contain chemicals affecting the strength of concrete. Salt water should not be used.

Super Cement is waterproofed in the making by the addition of a catalytic colloid to the cement clinker prior to grinding. The colloid forms a homogeneous matrix of 'glue' filling up all the voids and producing a strong dense concrete or mortar, water-, alkali-, oil-, and petrol-proof. Percolation tests made on slabs 1 in. in thickness composed of 1 part by weight of cement to 1 part washed Thames sand with 18 per cent. of water and properly matured show resistances from 50 to 200 lb. hydraulic pressure per sq. in. without penetration of moisture; and experience shows that an absolutely waterproof concrete can be made for use in waterlogged ground or below tide level.

The volumetric proportions suggested for various purposes are as follows:

Structure.	*'Super Cement'.*	*Aggregate.*	
		Sand.	*Stone.*
Foundations	1	3	6
Walls	1	2	4
Floors	1	1½	3
	1	2	4
Roofs	1	1½	3
Water tanks	1	2	4
Septic tanks	1	2	4
Concrete blocks or bricks	1	—	5
Concrete floor tiles	1	—	3
Stucco—1st coat	1	3	—
2nd coat	1	3	—
3rd coat	1	4	—

The following precautions (which can be adopted generally for all concrete work) should be observed: Store cement in a dry place and take steps to prevent damp air depositing moisture on the sacks; coat forms with oil to obviate adhesion of concrete, and build watertight to prevent leakage, as the water that escapes from concrete contains the most valuable part of the cement in solution; clean all wood, dirt, scurn, &c., out of forms and from the surface of all walls, and make certain that no greasy or oily surfaces remain on old work; avoid, if possible, concreting in freezing weather; thoroughly wet all surfaces with which the concrete is to come in contact; use a machine mixer wherever possible; if hand-mixed, gauge on a clean watertight surface; mix sand and cement to an even colour, wet the stone and then mix it with the cement and sand, adding enough water to make the concrete easy to handle and place; put concrete in position as soon after mixing as possible, tamp well and work large stones away from surface and sides; if concreting is not finished in one operation slurry surface before recommencing, and keep finished work damp and protected from sun and drying winds for at least seven days after completion.

Before rendering old walls or joining up with new con-

crete, if surface is dirty, greasy, or shiny, clean down with a solution of 1 gallon muriatic acid (spirits of salts) to 5 gallons of water, and then thoroughly remove all traces of the acid by washing with plenty of clean water.

Waterproofing Admixtures

It is impossible to set out here either the use or the mode of application of all the substances named above and intended for admixture with cement, so it must suffice to mention 'Colemanoid' (a liquid) and 'Pudlo' (a powder) as examples.

Colemanoid is a liquid chemical compound for adding to the gauging water for hydrating cement concrete in the mass, or mortar for renderings; a mode of addition which ensures thorough mixing. It is impenetrable by water, fresh or salt, heavy oils and acid solutions if gauged as directed by the manufacturers. For the 'mix' 1 gallon of 'Colemanoid' to 10 of water is recommended for mass concrete in retaining and other walls and foundations where very wet conditions obtain; for oil-proof, alkali- and acid-resistant concrete, 1 to 6; for cement renderings 1 part cement and 2 parts of clean sand gauged and tempered with a solution of 1 part 'Colemanoid' to each 10 parts of water. Floor toppings should be 1 in. in thickness and wall renderings $\frac{5}{8}$ in. thick properly coved and bonded to the floor and carried up 1 ft. above grade.

For *Pudlo* it is claimed that: the chemical substances of which it is composed react with the constituents of Portland cement and form a new silicious compound which spreads and completely fills every void, and on drying forms an impervious surface to the cement work; mixed with cement concrete, or with cement mortar for bedding brickwork, face renderings, or damp-proof courses the materials treated become perfectly watertight and impenetrable to moisture; waterproofed cement applied as a facing $\frac{1}{4}$ in. thick to breeze blocks during manufacture will make the most porous block waterproof;

added to cement used in the manufacture of artificial stone, inhalation and exosmose action of the cement is absent and rain is repelled instead of being absorbed; and that cylinders made with a mixture of 2 parts sand and 1 part cement waterproofed with 5 per cent. of 'Pudlo' (the proportion usually adopted in practice) will withstand a hydraulic pressure of 300 lb. per sq. in. without penetration of moisture into the substance.

To secure a satisfactory concrete, large, even sized, porous aggregates like broken bricks should be avoided. If used, waterproofing of the concrete should be omitted and dependence placed upon a waterproofed rendering. Stone ballast and sand form the best aggregate, the following sizes being recommended for use with 'Pudlo':

For a thickness of	1½ in.	use	¼ in.	(graded down to	⅛ in.)	aggregate.
,,	2	,,	⅜	,,		,,
,,	3	,,	½	,,		,,
	4	,,	⅝	,,		,,
,,	6–9	,,	¾	,,		,,

The proportions suggested are:

	Concrete.			Rendering on the concrete.		
	Thickness according to the size of the area to be covered.	*Proportions—ballast, sand, and cement.*	*Pudlo. (Weight in lb. per 100 lb. of cement.)*	*Thickness.*	*Proportions—sand and cement.*	*Pudlo. (Weight in lb. per 100 lb. of cement.)*
For ordinary conditions	3 to 9 in.	3 2 1	2	½ in.	2 and 1	5
If the rendering is omitted . .	4 to 9 in.	3 2 1	5			
For a varying flow of water .	3 to 9 in.	3 1 1	3	¾ in.	2 and 1	5
If the rendering is omitted . .	4 to 9 in.	3 1 1	5			
For flat roofs .	3 to 9 in.	3 2 1	2	¾ in.		5
If the rendering is omitted . .	4 to 9 in.	3 2 1	5		2 and 1	
For flat roofs on new (or old) concrete . .	1½ in.	1¾ ¾ 1	5			

Note: The proportion of 'Pudlo' is calculated to the cement and not to the aggregate.

Mass *v.* Surface Waterproofing

There can be no two opinions that the best method is to waterproof concrete in the mass, whether the material is in the form of concrete constructed *in situ*, or as blocks. A thin waterproofed cement facing, such as suggested above for breeze concrete blocks, is much inferior, as the facing is easily damaged by driving nails through it. Soakage also takes place through badly pointed joints into the unwaterproofed centre.

Wood Preservatives

Metallic paint preserves the surface of woodwork, but does not penetrate into the 'body', hence it is of little use for the preservation of wood embedded in or in close association with the soil. Wood exposed to wind and weather, inserted in the soil, or forming floors or structures contiguous to the soil, should be treated with an effectual preservative against dampness.

The following find a place amongst the many wet-resisting and preservative materials now obtainable, viz., Solignum, Fencol, Stoprot, Jodelite, and Peterlineum. For these are commonly claimed the prevention of decay from the action of moisture, dry rot, fungoid growths, and the ravages of the white ant and other wood pests.

The composition of the named liquids is not disclosed by the manufacturers. In general, wood preservatives have coal-tar as a base. For ordinary application the best and most effectual form is creosote, of which the following is a good specification, i.e. a distillate of coal-tar (creosote oil), the tar acids being not less than 6 per cent. and not more than 16 per cent.; entirely fluid at the ordinary temperature; free from water and from admixture of petroleum oil; possessing powerful and lasting fungicidal properties; a good penetrating property when applied cold to wood; and drying within an hour or two of its application. In determining the value of a damp-resister the

composition and properties here given should be considered.

The B.E.S.S. prescribes[1] that 'The material shall consist essentially of a distillate of coal-tar, and shall be free from any admixture of petroleum or similar oils'.

For building works a damp-proofing solution is generally applied with a brush, and the depth to which it is absorbed varies enormously with its nature and the class of wood being treated. Steeping in tubs or tanks containing a standard creosote produces better results, but the most effectual application is one applied under pressure (60 to 160 lb. per sq. in.) in closed iron cylinders or tanks.

Solutions of zinc chloride (1 to 4), copper sulphate, and corrosive sublimate are also used, applied by steeping or under pressure. Charring (for below-ground positions) is also adopted, but is inferior to a suitable preservative properly applied.

[1] British Engineering Standards Association, Specification No. 144, 1921.

V

DAMPNESS OF BUILDINGS: PREVENTIVE AND REMEDIAL MEASURES (1)

Site Coverings

IN some districts the by-laws permit the use of lime concrete for covering the ground surface within the external walls, but, as mentioned in Chapter IV, p. 71, it is not a damp-resister. Tarred asphalt is also recognized, but cannot be viewed as a suitable material unless finished with a sufficient thickness of natural rock asphalt. The best covering is a layer of cement concrete—waterproofed—not less than 6 in. thick and smoothed on the upper surface, or a thickness of 5 in. of ordinary cement concrete with a floating of 1 in. of waterproofed cement mortar or an equal thickness of rock asphalt.

Damp Courses

It has been shown that walls built either on or in the ground are subject to dampness from the underlying or abutting soil, due chiefly to capillary action. To prevent such dampness it is necessary to insert a damp-proof course, or damp course, i.e. a layer of impervious material which will act as a definite barrier to the movement of ground moisture.

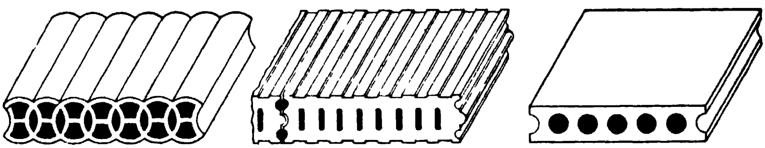
For horizontal damp courses laid through the thickness of a wall many substances are used, including sheet lead, slates, hard blue bricks, glazed and perforated stoneware slabs, a layer of waterproofed cement, tarred roofing felt, a layer of pitch and coal-tar, sheet bitumen, and asphalt in mastic form.

Sheet lead is effective when laid between two thicknesses of Portland cement with lapped joints of not less than

3 in. Contact with lime should be avoided, for in the presence of moisture the metal is converted into a carbonate of lead and thus rendered useless for the intended purpose. The weight of lead used ranges from 4 to 8 lb. per sq. ft.

Slates are quite satisfactory if laid in two courses with broken joints between two layers of Portland cement.

Blue Staffordshire bricks are used, laid as a double course with breaking joint in cement mortar, but the vertical and horizontal joints minimize the value of the damp-proofing.



27 28 29

FIG. 27. Board's glazed stoneware damp course.

FIG. 28. Doulton's glazed stoneware damp course.

FIG. 29. Taylor's glazed stoneware damp course.

Glazed and perforated stoneware slabs find favour and can serve as a continuous air-brick for under-floor ventilation. The slabs should have tongued-and-grooved joints as the straight joints allow the ascent of moisture. (Figs. 27, 28, and 29.)

Waterproofed cement mortar can be used if mixed and laid properly, but the substance is liable to crack. For 'Super Cement' the proportions should be 1 of cement to 2 of washed sand; for 'Pudloed' cement mortar 1 of cement to 2 of sand with 5 lb. of 'Pudlo powder' per 100 lb. of cement; and cement mortar waterproofed with 'Colemanoid', 1 of cement to 2 of sand gauged and tempered with a solution of 1 part 'Colemanoid' to each 10 parts of water. In each case the thickness should be 1 in. laid in a single coat.

Tarred roofing felt is not sufficiently impenetrable to

moisture and lasting to be suitable as a damp-proofing material.

Asphalt is a natural product and is found in two distinct forms, usually distinguished as (1) bitumen, and (2) rock asphalt.

(1) *Bitumen* is the softer of the two and possesses highly cohesive and plastic properties. The most noted product is that from the well-known 'pitch lake' in the island of Trinidad. It contains about 80 per cent. of carbon, 8 to 9 per cent. of hydrogen, and varying proportions of oxygen, nitrogen, and ash. Refined bitumen melts at 194° to 212° F., is absolutely impermeable to water, and has been used from time immemorial for waterproofing and preservative purposes.

(2) *Rock asphalt* is a calcareous (limestone) rock impregnated naturally with bitumen (about 8 per cent.) and is marketed in two classes—Foreign and British, the former being a natural product and the latter a manufactured article. Of the foreign asphalts 'Seyssel' is excellent in quality. 'Limmer', 'Brunswick', and 'Vorwohle' are somewhat coarse grained, of a sandy substance, and although differing from 'Seyssel' make a good mastic asphalt if properly prepared. In preparing the material for its marketable 'mastic' form the rock is crushed to a fine powder and heated in cauldrons along with about 10 per cent. of genuine refined Trinidad Lake Bitumen which acts as a flux. Rock asphalt is supplied in block form ready for melting. Laid as a mastic $\frac{1}{2}$ to $\frac{3}{4}$ in. in thickness it may be accepted as superior to all other materials for damp-proofing.

Bitumen is readily adulterated during the refining process essential to fitting it for use by the addition of vaporous and other oils which reduce the otherwise permanent cohesive character of the properly refined material. Genuine rock asphalt is also open to adulteration by adding sand, gravel, pitch, and tar; and a cheap and entirely artificial asphalt is not unknown made of ground British

limestone, sand, pitch, and tar mixed with highly adulterated bitumen. Bitumen should therefore be specified as 'genuine pure refined Trinidad Lake Bitumen'. A serviceable specification for rock asphalt suitable for damp-proofing is: Natural foreign asphalt equal in quality to that obtained from the 'Pyrimont' mine in Seyssel, the Val de Travers 'Limmer' mines, or other approved mine, fluxed with pure refined Trinidad Lake Bitumen, the two ingredients to be respectively about 79 and 18 per cent: and constitute about 97 per cent. of the mastic.

Sheet bitumen varies enormously in value. It may be of pure refined bitumen well tempered without 'backing', or on a basic material of good canvas or a core of woven steel wire—all of excellent quality and eminently suited for the intended use; or merely a fabric of paper, felt, or fibre impregnated and covered with a rubbishy compound containing much coal-tar and pitch. Inferior makes are easily torn and fractured under strain, the bitumen used becomes quite soft at relatively low temperatures—115° to 160° F.—and readily squeezes out. A suitable material should be absolutely free from coal-tar and pitch and not appreciably softened at 212° F. 'Callender' sheeting is a well-proven make, and its impermeability is shown by resistance to a hydraulic pressure test of 80 lb. per sq. in.

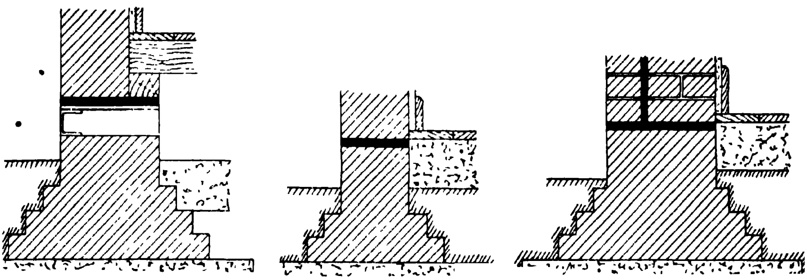
For damp courses bitumen is made up in sheet form of varying thicknesses, in widths $4\frac{1}{2}$ to 36 in. and usually in rolls about 24 ft. long.

A good sheet bitumen possesses one advantage over rock asphalt, viz. its pliability, which may prevent fracture should a settlement take place in the structure in which it is incorporated.

Sheet lead and bitumen are combined in the roll sheet damp course known as 'Ledkore', which consists of a core of sheet lead (of varying weight—three grades) between two layers of 'densely compressed and thoroughly bituminized material'. It is impervious to water, elastic, indefectible, and unaffected by extremes of temperature.

Another lead-core damp course of this description is 'Leadbitu'.

Pitch obtained from tar produced in the destructive distillation of coal, mixed with sufficient tar to avoid cracking and laid as a mastic, forms a jointless damp course, but is liable to soften at a low temperature and be



30 31 32

FIG. 30. Horizontal damp course with means of ventilation to hollow floor.
FIG. 31. Horizontal damp course for wall with abutting solid floor.
FIG. 32. 'Bitubond' vertical and horizontal damp course.

squeezed out by the weight of the superimposed building. It is an inferior damp course and cannot be recommended.

Position of Damp Course

The best position is six inches above the ground level, below the wood plate where the floor is hollow, and level with the upper surface of the concrete where the floor is solid. Figs. 30 and 31 illustrate forms of damp courses and the suggested positions. To prevent the downward soakage of water in chimney stacks a similar horizontal damp course is sometimes inserted through the brick-work, &c., at the junction with the roof. For this position a layer of 'Super Cement' mortar (1 : 2) or two courses of slates in cement are preferable to bitumen or asphalt.

Exposed Walls

In exposed positions where the prevailing winds bring much rain, moisture is carried into and through the walls

by the action previously described. This occurs even where the stone or brick cannot be classified as porous, the fault being with the jointing. Walls 18 in. or more in thickness if built in cement mortar are not seriously affected in this way, but 9- and 14-in. walls built in lime mortar with doubtful joints are commonly subject to dampness thus circulated. To cope with such weather conditions one of several methods may be adopted.

Vertical damp courses. The insertion of a damp proofing substance throughout the length and height of a wall on the lines shown in Fig. 32 prevents the permeation of moisture. A good natural rock asphalt suitably fluxed should be used, and for the purpose 'Bitubond', which is heated and run in a molten state into a cavity not less than ½ in. wide formed by two parallel walls, thus filling up the interstices in the inner wall faces and bonding the two leaves together, is effective if such care is taken as will avoid breaks or gaps in, or honeycombing of, the asphalt by pieces of brick or mortar, or through careless 'running' of the mastic.

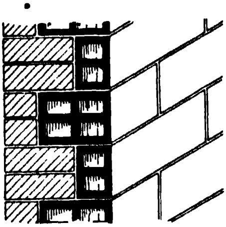
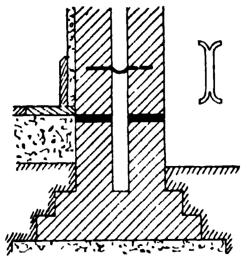
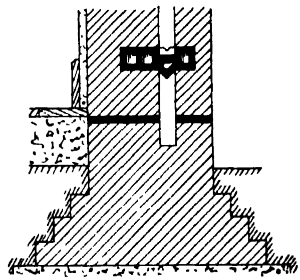
This material is acid-resisting, water- and vermin-proof, and a non-conductor of sound and heat. 'Hygeian Rock' and 'Tenax' are also useful substances possessing similar characteristics.

Rendering. The absorption of moisture into brick, stone, and concrete walls can be prevented by the application of a rendering of waterproofed mortar. Such rendering may be in the form of a floated surface finished plain stucco, or as roughcast with a sand dash, or stone and pebble dash finish.

Whatever the finish, the wall should first be rendered ¾ in. thick in two coats of ⅜ in. with 'Super Cement' (1 to 2 of washed sand); 'Pudloed' mortar (1 : 3 with 3 lb. of Pudlo powder to every 100 lb. of cement; exposed positions 1 : 2 and 5 lb. of powder); 'Colemanoid' mortar (1 : 2 with 1 of 'Colemanoid' to 10 parts of water); or other guaranteed waterproofed cement or waterproofing medium.

Terra-cotta and stoneware facings. Moisture penetration may also be resisted by using terra-cotta or stoneware facings (Fig. 33), but the damp-resisting quality of the surface is weakened by the number of joints. If used, materials should be selected with vertical and horizontal over-lap or tongued-and-grooved joints.

Tiling and slating. Instead of a cement rendering, the exterior surface of a wall is sometimes tiled or slated, these

33 34 35

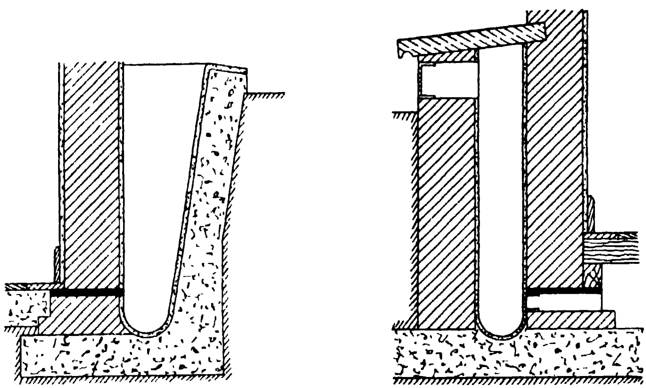
FIG. 33. Terra-cotta hollow-block facings.
FIG. 34. Cavity wall with galvanized-iron ties.
FIG. 35. Cavity wall with glazed stoneware ties.

materials being bedded on with cement mortar and lapped in the fashion adopted for roof work. The disclosed weakness of the method is cracking of the tiles or slates and liability to 'slipping'. To prevent the latter the wall should be battened to receive the nibs of the tiles or the slate nails, the spaces between the battens being roughly flush-rendered with cement mortar as a bed for the tiles or slates. For fixing the slates copper nails should be used.

Tiles and slates can usefully be employed for covering vertical woodwork, but for solid walls of brick or cement a suitable rendering or rough-casting as previously described gives more lasting results at a lesser expense. For covering walls abutting on the soil, tiles and slates are unsatisfactory owing to the probability of absorption by capillarity through the many laps or joints.

Hollow or cavity walls. The usual type is as shown in

Figs. 34 and 35, which illustrate 11- and 15½-in. walls, each with a 2-in. cavity. With such construction no cross bonding is possible, so the leaves or portions must be held together with galvanized iron, stoneware, or other suitable ties, or bonding bricks of the kind illustrated; these should average four to every superficial yard. Ample provision is also required in the way of airbricks—not less than one brick to every five feet horizontal run of a cavity wall at



36 37

FIG. 36. Open area between wall and soil.
FIG. 37. Covered dry area between wall and soil.

each floor level—for the purpose of allowing a circulation of air through the contained space.

Up to recent years the Building Acts and by-laws generally required cavity walls to be constructed with a wall on one side of the hollow space of the full thickness prescribed for the particular height, length, &c., but the development of State-aided housing schemes has altered the position and the Minister of Health now permits by revised by-laws thinner walls constructed of various materials and a wide range of method. (See Chapter III, p. 54.) For the reasons previously adumbrated (Chapter III, p. 58) cavity walls of this type cannot be accepted as impenetrable to moisture; therefore, unless constructed

of jointless waterproofed materials, an external rendering should be provided.

Walls abutting against the Soil

For walls forming a basement special precautions are necessary where they abut upon the soil. The precaution may take the form of a dry area, as in Figs. 36 and 37. With the open area shown in Fig. 36 provision should be

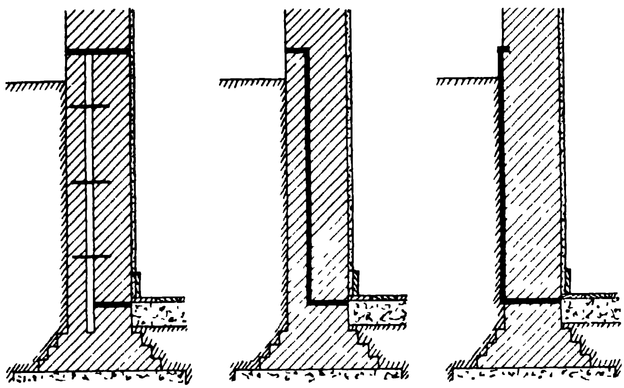


FIG. 38. Basement cavity wall with horizontal damp courses.
FIG. 39. Vertical and horizontal asphalt damp courses in basement wall.
FIG. 40. Basement wall with horizontal damp course and exterior rendering of mastic asphalt.

made for drainage by means of a gully trap discharging to a drain or soakaway; and adequate ventilation where the area is covered, as in Fig. 37.

If the basement walls are of concrete they can be waterproofed throughout with 'Super Cement' or one of the mediums previously described. Brick, stone, and concrete walls can be constructed with a cavity as in Fig. 38, or with vertical and horizontal damp courses as in Fig. 39. Alternatively to using mastic asphalt, 'Callendrite' bitumen sheeting can be fixed with 3-in. vertical over-lap joints sealed with a hot jointing iron. Instead of these methods the outer surface of the wall can be rendered

with mastic asphalt or waterproofed cement mortar in conjunction with a horizontal damp course as in Fig. 40.

Cellars under footpaths, &c., should be surrounded by damp-proofing as in Fig. 41.

Basements in Waterlogged Ground or subject to Water Pressure

Where basements are constructed in waterlogged ground the usual concrete site covering often fails to prevent the introduction of subsoil water, particularly where the basement is much below the ground level or is affected by water pressure. Such cases may be dealt with by (1) using waterproofed concrete throughout for floor and walls, or (2) continuing the vertical damp course through the site concrete or floor (mastic asphalt or Callender's sheeting being employed for the purpose), thus converting the basement into a watertight tank. If the hydrostatic head is considerable it may be requisite to reinforce the upper or holding-down layer of concrete. Figs. 42, 43, 44, and 45 illustrate methods.

In such cases as these it is sometimes a problem to know how to keep the water down to a level to allow of the floor concrete being laid. If the inflow is small it may be sufficient to excavate a small sump immediately under the floor, or outside the structure if practicable, to keep the water pumped out until the floor is set and dry, and then to empty the sump by pumping or baling and fill in with waterproofed concrete.

Where the infiltration is too great to allow of this simple treatment one or more sumps with lines of earthenware subsoil drains may be provided, each sump being fitted with a screwed or flange-jointed suction pipe for attachment to a pump suction as in Fig. 46. The floor can then be laid as required with all necessary reinforcement, the pumping being continuous during the laying and for seven days after or until the concrete is well hardened. On completion the suction pipe can be sealed below the floor

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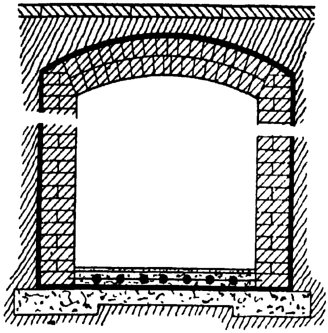

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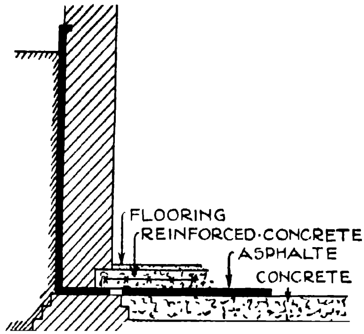

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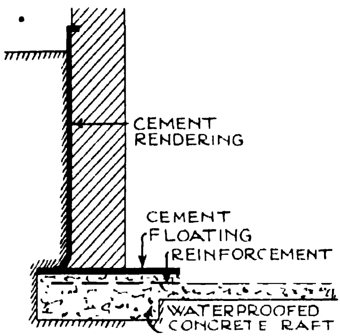

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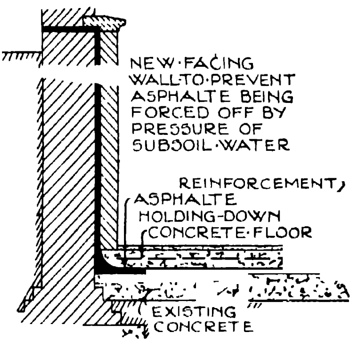

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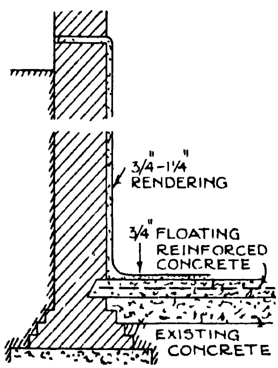

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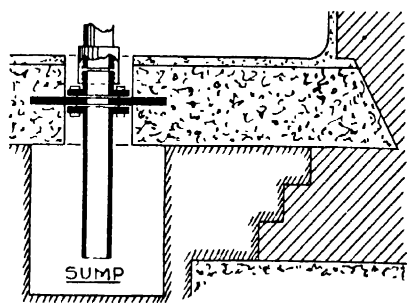

FIG. 41. Cellar with exterior rendering of mastic asphalt and damp course through floor. FIG. 42. Basement in waterlogged ground (new work). Asphalt rendering on exterior of walls and damp course through reinforced concrete floor. FIG. 43. Basement in waterlogged ground (new work). Waterproofed and reinforced cement concrete floor and waterproofed cement floating and rendering. FIG. 44. Basement in waterlogged ground (old work). Asphalt rendering on internal face of walls and floor with retaining wall and holding-down layer of reinforced concrete. FIG. 45. Basement in waterlogged ground (old work). Concreting, floating, and rendering with waterproofed cement. FIG. 46. Sump fitted with pump suction-pipe for removing subsoil water.

level and the concrete made good. A 'Super Cement' floor 12 in. in thickness would probably be found sufficient to meet all such exigencies as appertain to the treatment of buildings constructed in waterlogged soil.

Damp-proofing Reinforced Concrete Work

Damp-proofing of reinforced work is best attained by waterproofing the whole of the concrete. Failing this, a waterproofed cement rendering may be applied to the exterior face work. For such work 'Super Cement' can successfully be used.

Joints of Brick- and Stone-work

Some architects have a fancy (or weakness) for wide joints in brickwork, frequently allied to a decision to finish with a 'struck' joint in preference to one that is pointed. Such joints when made with lime mortar facilitate the entry of moisture and nullify the value of the bricks if these are non-absorbent. Joints in both brick- and stone-work should be as close as practicable and made with waterproofed cement mortar grouted in so as to fill all vertical crevices. So made, pointing can be dispensed with, the joints being 'struck' as the work proceeds. If lime mortar is used, the joints ought to be raked out not less than 1 in. and then well pointed with waterproofed cement. The use of 'killed' cement should be avoided.

Copings and Weatherings

Walls of brick or stone should be coped with non-absorbent natural stone (such as Ancaster or Portland), or artificial stone, weathered and throated so as to throw off rainwater and prevent soakage into the walls (Fig. 47 (C)). For brick walls, drip tiles or tile creasing (two courses of the latter with broken joints) with a non-porous brick on edge bedded and pointed in cement may be used (Fig. 47 (A) and (B)).

Chimney stacks should have weathered caps with tile

overhang or other suitable drip, and all projecting cornices and sailing courses ought to be weathered and throated (Fig. 47 (D) and (E)). Waterproofed cement is recommended for all bedding, pointing, and rendering, and the insertion of a damp course in all chimney stacks as well as in all walls standing more than 18 in. above the roof. Alternatively, all brick-work above the roof can be rendered with waterproofed cement mortar.

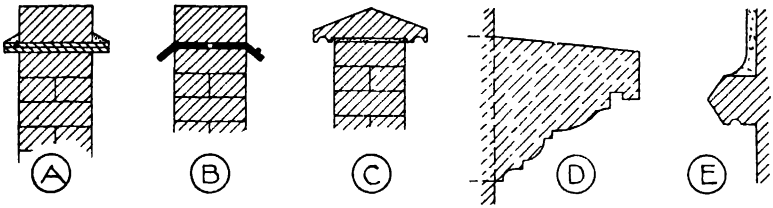

FIG. 47. Copings and weatherings. A. Tile creasing. B. Drip tiles. C. Brick or stone coping. D. Weathered and throated cornice. E. Throated drip or sailing course.

Floors

The site covering may form the floor, or the latter may be constructed above it with a hollow or intervening space between.

Solid floors are vermin proof and, laid properly, damp-proof. For commercial buildings, such as factories, warehouses, and other premises subjected to wet processes or heavy haulage, a hard and impervious surface is needed, and may be formed with waterproofed concrete and a surfacing of rock asphalt or waterproofed granolithic cement, which can be relied upon to be dustless as well as impervious.

Cement is too cold and hard or non-resilient for dwellings, and is not the ideal flooring for workshops and other places where an impervious surface is not compulsory. Many composition jointless floorings for laying *in situ* on sub-floors of concrete are now obtainable. These mainly consist of wood fibre or asbestos mixed with magnesite, are supplied in various colours, and are said to be

resilient and dustless. Care should be exercised in selection, for some disintegrate readily and produce much dust, while others in contact with air and moisture cause corrosion of any embedded iron, and, moreover, possess a surface which is readily attacked and destroyed by dilute mineral acids. Satisfactory floors may be formed with a concrete base 6 in. in thickness finished with wood blocks laid in emulsified bituminous plastic or mastic compound such as 'Bitumac', a carbon emulsion as 'Protex', or other suitable wood block flooring composition.

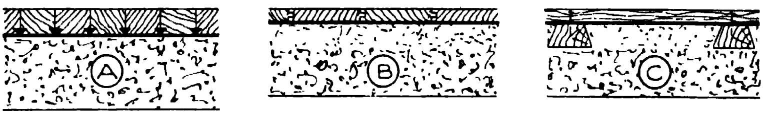

FIG. 48. Solid floors. A. Wood blocks on ballast concrete. B. Boarding nailed direct to breeze concrete. C. Boarding fixed to wood fillets embedded in concrete.

Alternatively, the concrete site covering can consist of a layer of 4 in. of ballast concrete and a topping of 2 in. of breeze concrete consisting of pure, clean, and thoroughly burnt clinker gauged in the proportion of 1 part of waterproofed cement to 6 parts of aggregate, carefully levelled, with floor boards nailed direct to the breeze after giving the latter two coats of bituminous composition—one coat being applied as the flooring proceeds. Another alternative is to lay the concrete (ballast or ballast and breeze), inserting creosoted wood fillets and laying the floor boards as just described. Whichever method is adopted the use of waterproofed cement concrete is recommended. Fig. 48 illustrates floors of the kind described.

Hollow floors consist of battens or boards nailed to wood joists supported by wood plates and sleeper walls as in Fig. 30. Such floors are more affected by dry- and wet-rot than solid floors laid as above. Dry-rot is a form of decay in timber caused by the growth of fungi in the dark with favourable conditions of heat and moisture, such as obtain under a hollow floor insufficiently ventilated. Wet-rot is

disintegration resulting from the oxidation of lignin (cellulose or woody fibre) in the presence of air and moisture, moist air at a temperature of 60° F. or thereabouts providing the most favourable condition. To avoid the ravages of decay from these causes it is imperative that sufficient under-floor ventilation should be provided to prevent the accumulation and deposition of moisture.

The construction of hollow floors ought to be limited to levels above the ground surface or where adequate dry

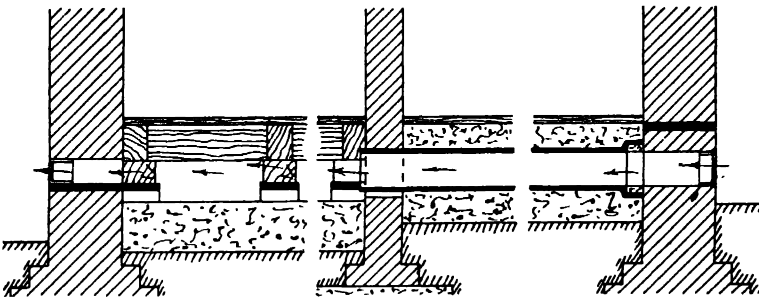

FIG. 49. Air duct through concrete floor to allow for ventilation of hollow floor.

areas can be constructed. For ventilation, ample openings should be left between sleeper walls and a sufficient number of air-bricks fixed in opposite external walls so as to secure a through current of air. Where a solid floor impedes through ventilation, as in Fig. 49, pipe air-ducts can be laid as shown. Wood plates should be laid on an approved damp course and all under-floor timbers creosoted in the best manner—a precaution which will go a long way towards preventing both dry- and wet-rot.

Window Frames and Sills

Wood frames are fixed in rebated openings, or openings in the clear. If the latter, cement mortar reveals should be provided on both the inside and outside of the frames. Casement sashes should have a hooked joint and the frames be provided with water-grooves to prevent capillarity.

One of the commonest causes of dampness in walls below window openings is the absence of properly weathered, grooved, and throated sills. A jointless sill is naturally the best as affording the least chance for the entry of water, but tiles can be used if non-porous and laid in two courses with breaking-joint. Brick sills have

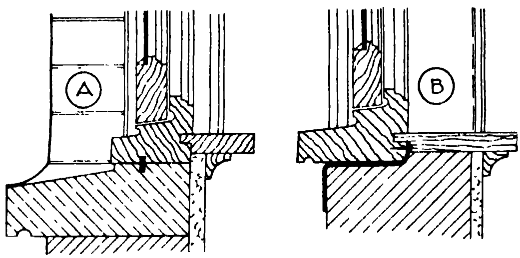

FIG. 50. Window sills. A. Weathered and throated wood and stone sills with water-bar. B. Weathered and throated wood sill with metal flashing.

so many joints that it is difficult to make and maintain them in a weatherproof state. If joints in wood, stone, or concrete sills are necessary they should be tongued-and-grooved or lapped in such fashion as to break the otherwise straight joint. For wood sills on stone, brick, or concrete a water-bar is essential. Where wood-framed sills are fixed alone it is a good plan to put a lead or copper flashing under and turned up against the inside edge. Fig. 50 illustrates details.

Tiled, slated, or rendered walls can be finished at window-head level with a projecting course or drip. This prevents water running back under the arch.

To protect door and window-frames, lintels, &c., projecting in, or extending across, the cavity in a hollow wall against moisture that may enter or be condensed in such cavity, the woodwork should be covered throughout with a lead damp course, or other impervious material. This protection is prescribed in the Model by-laws.[1]

Steel windows are now largely used both for good-class

[1] Urban, Series IV, 1925.

and cottage property. If of standard pattern and fixed in a proper manner they are proof against the entry of rain, but inattention to detail involves much trouble in this respect. They can be inserted in wood frames, but as these are much subject to warping and shrinking, the best results

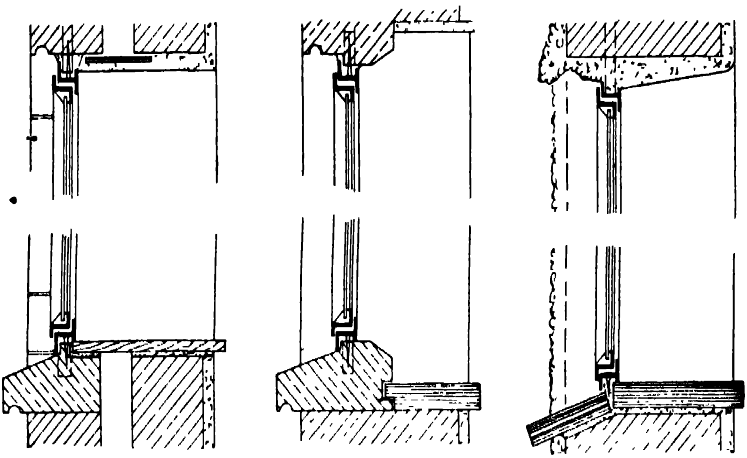

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FIG. 51. Metal casement with stone sill in cavity wall.

FIG. 52. Metal casement with stone sill in plain brick or stone wall.

FIG. 53. Metal casement with tile sill in brick wall finished rough cast.

are obtained when fixed in stone, brick, or concrete openings. It is usual to allow a margin of $\frac{5}{8}$ or $\frac{3}{4}$ in. between the frame and the enclosing brickwork, &c., the margin being well filled in with cement mortar (1 and 2), or a cement reveal formed inside and outside. Figs. 51, 52, and 53 illustrate sections of standard cottage type fitted in a cavity wall, a solid wall in plain brickwork, and one with a rough cast finish.

VI

DAMPNESS OF BUILDINGS: PREVENTIVE AND REMEDIAL MEASURES (2)

Roofs and Roof Coverings

THE form of construction in respect of the facilities made for the carrying off of rain-water, and the materials used and method of fixing so as to prevent the entrance of water is all-important.

Cement. Floatings and renderings for solid concrete or patent hollow-block flat and sloping roofs should be in suitably waterproofed cement not less than 1 in. in thickness, finished at wall junctions with a cement fillet and carried up as a skirting as in Fig. 54. The drawback of a cement finish is its liability to crack.

Rock asphalt. Whether laid on a concrete, hollow block, or boarded roof, the asphalt should be in at least two layers with crossing and breaking joints and a total thickness of $\frac{3}{4}$ to 1 in. An angle fillet should be fixed or formed and a skirting 6 in. in height turned into the wall, or, in the case of parapet walls, carried through the full thickness. Where the discharge is either into an eaves gutter or a rainwater head the asphalt can be carried over with a lead apron or drip piece. If the outlet is into a cesspit this can be lined with asphalt and furnished with an outlet pipe with socket or flange bedded in the asphalt, a mode of connexion also adaptable to cases where the discharge is direct from a gutter. For steep-pitched roofs, dormer cheeks, &c., the asphalt can be laid on an expanded metal reinforcement with felt underlayer. This provides a good key for the asphalt and effectually prevents 'creeping'.

Combined rock asphalt and sheet bitumen. Rock asphalt is liable to crack through vibration and shrinkage of

timbers, settlements, and other causes, to avoid which a combined covering of rock asphalt and sheet bitumen in layers may be used. Of this kind are 'Permaphalt', which consists of two separate layers of sheet bitumen sealed together with bituminous mastic, a layer of ordinary roofing felt, with a finishing surface layer of rock asphalt; and 'Lim-a-lith', which takes the form of two layers of compressed sheet bitumen, a layer of flax-felt joined with bituminous mastic, and a layer of rock asphalt.

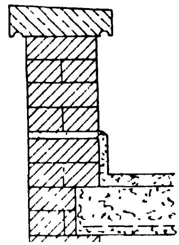


FIG. 54. Reinforced concrete roof with waterproofed cement floating, skirting, and damp course through wall.

Sheet bitumen. Bitumen in sheet form and fibrous material in sheets saturated and coated with bitumen are used for both flat and pitched roofs. Callender's sheeting is a good example of pure bitumen and 'Ruberoid' of a bituminized sheet fabric. When laid as a single sheet the lapped joints are usually 2–3 in. 'Ruberoid' is nailed down, with bituminous mastic or cement between the laps, and a coating is applied on the nailheads and finished seam or joint. Callender's sheeting is joined by softening the lappings with a jointing iron heated to a dull red heat. On flat roofs the exposed edges should not be laid against the fall or stream. On pitched roofs the practice varies; some makers suggest horizontal lappings as for flats, and others vertical laps running from ridge to eaves.

Sheet bitumen when laid on boarded flat roofs and in wood gutters must, to conform with the Fire Insurance Companies' and many local authorities' requirements, be covered with an approved material which will make the asphalt fireproof from the outside. This is met by a covering of 2 in. of binding hoggin (not coarser than will pass a $1\frac{1}{2}$-in. ring) or $\frac{3}{4}$ in. of loamy sand and $1\frac{1}{4}$ in. of shingle, kept in position by a metal or wood gravel curb at the eaves or around the rain-water outlet. Instead of

hoggin, 1 in. of breeze or other concrete or tar-paving is accepted. On roofs of concrete and cement construction no such covering is necessary, but if the finishing mastic or varnish is covered with fine clean grit greater resistance is given to traffic.

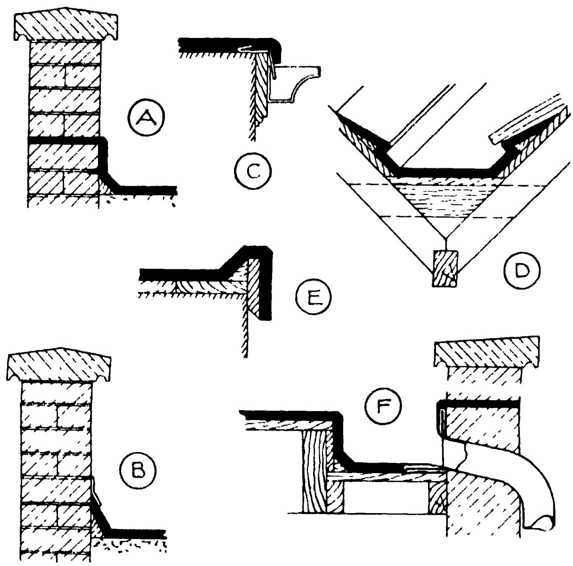


FIG. 55. Rock asphalt roof coverings. A. Skirting against and damp course through wall. B. Metal flashing to asphalt. C. Discharge to eaves gutter with metal drip. D. Valley gutter to tiled roof. E. Detail at verge. F. Parapet gutter with pipe outlet.

Roofs covered with sheet bitumen and similar sheet materials can be made perfectly watertight, but cannot be regarded as the equal of those having a rock asphalt finish.

Tarred roofing felt cannot be accepted as a suitable roof covering for buildings of a permanent character.

Fig. 55 illustrates usual methods for securing watertight joints between asphalt and bitumen roof coverings and walls, &c., and other details.

Sheet metal. Sheet and cast lead and sheet copper and zinc are eminently fitted for roof coverings. The life of zinc, however, is much shorter than that of lead and copper.

Lead expands and contracts freely on subjection to atmospheric conditions, and, if rigidly fixed, buckles and cracks. To obviate this, individual pieces should not measure more than 7 ft. × 3 ft. 6 in. and the method of laying should allow as much freedom of movement as is compatible with sufficiency of fixing. Copper and zinc also expand and contract but not to the same extent as lead: regard should nevertheless be had to this probability. Sheets of copper and zinc for roofing purposes respectively have maximum measurements of 8 ft. × 3 ft. and 8 ft. × 4 ft., thus limiting the area which can be covered by one piece of metal.

Lead cesspits may be made by soldering and the outgo pipe wiped in, but with these exceptions soldering should be avoided. If a sealed joint is necessary elsewhere a burnt seam should be made. Much soldering is done on cheap zinc roofing. Joining in this fashion is inadvisable as it is the cause of many defects. With good copper and zinc work joining is by rolls and welts.

For flat work the various pieces of metal should be joined by solid or seam rolls (preferably the former, as the latter are bruised and trodden down by traffic and become leaky), and by drips not less than 2 in. in depth. Drips should also be formed in gutters. Lead, copper, and zinc sheets may be joined by welts for vertical positions. If the covering material is lead, drips should have capillary grooves into which the undercloak can be worked.

At wall junctions the metal should stand up 6 in. and be covered with an apron flashing having 4-in. laps or passings turned and lead-wedged into the wall with sufficient tacks and clips to hold the edges of the flashing close to the wall. At eaves gutters the metal should be worked over edge of flat, &c., with holding-down tacks or clips; in parapet, and other gutters taking tiles or slates, over tilting pieces (to prevent capillarity and afford a good drip) and carried up 6 in. under the tiles or slates.

Lead on sloping surfaces has, by reason of its weight

and property of expansion, a tendency to 'crawl': hence it is best used in smaller pieces than for flats. One method of fixing on acute slopes is to pass the top edge of sheet between the boarding and nail on the inside. For vertical positions secret tacks may be utilized. To prevent capillary action at the 'passings' a groove should be cut in the boarding and the undercloak worked into it. Figs. 56 to 65 illustrate such details as are essential to secure watertight joints.

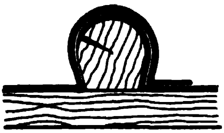
Tiles and slates are only suitable for roofs designed with a 'pitch'. The pitch of roofs commonly ranges from 30° to 60° but a flat pitch of less than 30° and a high or steep pitch greater than 60° are also adopted. The London Building Acts[1] limit the plane of the surface of the roof of a building of the warehouse class to an angle of 47° with the horizon; other buildings, 75°. Such restrictions do not, however, apply to turrets, towers, or spires.

For tiled roofs the pitch should not be less than 40° and for slated roofs $26\frac{1}{2}$°, since a flat pitch favours capillary action between the roof layers. Better minima respectively are 45° and 30°.

To keep out rain, tiles and slates are 'lapped', the vertical joints being 'close up' and the horizontal varied according to the pitch of the roof and the pattern of the tile or slate. In plain tiling and straight slating the 'lap' means the distance the tile (or slate) overlaps the next but one below it; with many patent tiles, diagonal slating with single laps, and asbestos cement tiles, the 'lap' means the distance over the head of the tile or slate immediately below.

Plain tiles and slates lapped as in Fig. 66 (A) and (B) provide the most watertight form. Single-lapped tiles, such as pantiles and some patent tiles with inter-locking joints, permit the entry of driving rains, necessitating the use of an underlining of sarking or non-porous felt. Of patent tiles, Fig. 66 (C) is a good example.

[1] 1894–1908.



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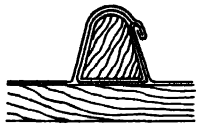

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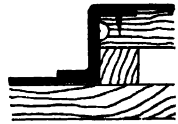

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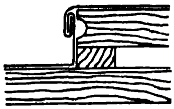

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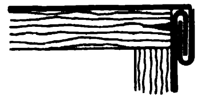

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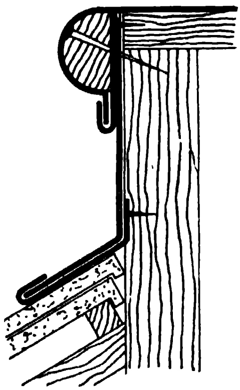

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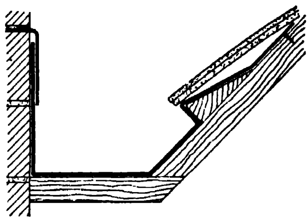

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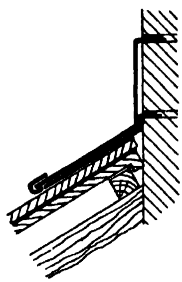

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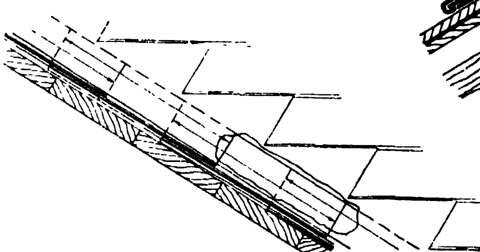

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FIG. 56. Lead-covered roll.
FIG. 57. Welted-copper roll.
FIG. 58. Lead-covered drip.
FIG. 59. Welted-copper drip
FIG. 60. Double welt.
FIG. 61. Welted edge for flat roof.

FIG. 62. Torus roll for edge of flat, with flashing to tiled roof.
FIG. 63. Parapet gutter.
FIG. 64. Step flashing and soakers.
FIG. 65. Apron flashing for roof abutting on brickwork.

Plain tiles on a pitch of not less than 45° should have a lap of 3 in.; below 45° and down to 40°, 3½ in. For slates laid on a pitch of not less than 35° a lap of 2½ in. may be taken as sufficient, with 3 in. for a pitch down to 26½°. Pantiles, patent tiles (generally), and slates fixed diagonally with single laps should have the following minima:

Pitch (degrees)	*Minimum lap (inches)*
35	2¾
33	3
30	3½
25	4

Old-fashioned tiles are holed and fixed by oak pins or pegs, an unsatisfactory fixing as the pins are liable to decay.

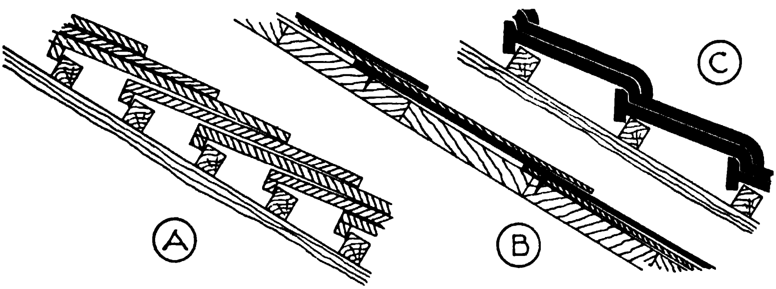

FIG. 66. A. Plain tiling with 3½-in. lap. B. Slating with 3-in. lap. C. Board's 'Weatherblock' tiles with 1½-in. lap.

Modern patterns generally have nibs for hanging the tiles on to the battens, with holes for nailing if required—as when fixed vertically. 'Torching', i.e. pointing the underside with lime and hair mortar, is sometimes done to keep out wind and dust, but given sufficient lap and fixing the practice is not necessary. A better arrangement is to board the roof and provide an underlining as mentioned later. Slates should be holed and fixed with copper nails.

In fixing tiling and slating a double course should be provided at eaves, extra size (tile—or slate—and a half) for alternate courses at verges and walls abutting on roof slope, with verge and eaves tiles overhanging at least 2 in. to furnish a drip clear of wall or into gutter. Bedding of

tiles (except valley, hip, and ridge) should be avoided as this tends to stop ventilation and to allow the accumulation of moisture detrimental to the roof timbers. The exposed edges of verge tiles should be well pointed with cement mortar.

Tiled roofs can have special valley tiles, and both tiled and slated roofs can be arranged with 'swept' Tudor valleys instead of those ordinarily provided for. Valley gutters should be lined with lead, copper, zinc, or asphalt worked over tilting fillets. For hips and ridges tiles can be used bedded in cement mortar, the best weather-resisting pattern having lapped or capped joints; or roll cappings of lead, copper, or zinc with laps or passings of not less than 6 in. For hips and ridges slate rolls and wings fixed with screws or nails are used, but the butt joints are seldom watertight.

In cheap work tiling and slating are made good to abutting brickwork with cement fillets, which crack and let in water. A better method is the use of lead, copper, or zinc soakers and stepped or apron flashings. Secret lead gutters are sometimes formed at ridges, hips, and walls abutting on roof slope, but as in fixing tiling or slating the edges of the metal are apt to be flattened, thus reducing the value of the gutter, and since the latter tends to become choked with dust and debris, thus accelerating capillary action, the methods previously mentioned are the better.

Asbestos cement tiling or slating. During recent years much development has been seen in the use of tiles or slates made of compressed asbestos fibre and cement, a roofing material which is lighter, easier to fix, and less expensive than clay tiles and slates. These tiles are made as pantiles, and as flat tiles for straight and diagonal fixing, with single laps of $2\frac{3}{4}$ to 4 in. according to pitch of roof or exposure to winds and driving rains. (See p. 104 for laps.) Copper disk rivets are mostly used for fixing. Hip and ridge tiles or capping of the same material with butt or lapped joints are supplied.

Asbestos cement sheets are manufactured in the form of Roman and other tiles and as straight and curved corrugated sheets to various sizes. Roman tile sheets measure 4 ft. × 1 ft. 10½ in. with a roll of 2 in. Fixing is by means of galvanized screws and limpet washers through the rolls, or galvanized iron clips. A minimum horizontal lap of 4 in. is needed.

Straight corrugated sheets for plain roofs can be obtained measuring up to 8 ft. × 3 ft. 7¼ in. and 10 ft. × 2 ft. 6 in. The side laps vary from 2 to 6 in. The horizontal laps should be at least 6 in. for a pitch of 30°. Fixing is by galvanized iron screws and washers. For a flat pitch (less than 30°) and for exposed positions a mastic composition joining material is suggested for the purpose of making the lapped joints wind- and water-tight.

Corrugated iron or steel sheets are of various sizes, the maximum being 8 ft. × 3 ft., and are galvanized to prevent oxidization. A new form of sheeting is 'Cellactite', which consists of sheet steel covered with an acid- and weather-resisting substance. The mode of, and the precautions to be observed in, fixing are the same as for asbestos cement sheets.

Slate and stone slabs. Slate and thinly stratified stone slabs are utilized for roofing in districts where other materials are difficult to obtain, and in certain instances, for effect. The slabs vary in size and are commonly 1 to 2 in. thick. They need strong roof timbers and require fixing in respect of laps and flashings in a similar fashion to slates of ordinary thickness.

Thatchings. The pitch of a roof for thatch ought not to be less than 45°. Good reeds, wheat, or rye straw are the best materials. As eaves gutters are of little use the roof should overhang not less than 2 ft. so as to protect the walls from splashing. Verges also should be well overhung.

Shingles made of oak are occasionally used as roof coverings. They should be of split oak and their use restricted

to high-pitched roofs where rain-water is quickly thrown off. Fixing should be by copper nails with laps as for plain tiles.

Underlinings

Sloping roofs are best if close boarded and covered with an underlining (or underslating) to receive tiles, slates, asbestos cement, and other sheet coverings. Where the roof covering is laid with single laps or the roof is of flat pitch, an underlining is almost obligatory if the access of driving rains to the interior is to be prevented. Such underlinings are often laid across open rafters, but the practice is not a good one owing to sagging of the material.

The selected material should be inodorous, watertight, and proof against damp-rot and vermin. Felts impregnated with bitumen, such as 'Rooferite', 'Permaflex', and 'Bitu Felt' are suitable; also Willesden metallized water- and rot-proof paper. The material should be lapped both vertically and horizontally and well nailed.

Falls for Flat Roofs

The minimum fall for metal-covered roofs may be put at $1\frac{1}{2}$ in. in 10 ft.

Cement- and asphalt-covered roofs should have a minimum fall of 2 in. in 10 ft. Some roofing firms specify 3 in. in this length.

Ventilation of Boarded Asphalt-covered Roofs

Where rock asphalt or bitumen sheets with sealed joints are employed on boarded roofs lathed and plastered on the underside—thus leaving an air-tight cavity—provision should be made for ventilation in the form of air-bricks in the external walls and a number of perforations in the timbers. If this is not done condensation of moisture may give rise to rotting of the latter.

Roof Glazing

Glass expands and contracts with atmospheric changes

and provision should be made for this and for the expansion of the framing when made of metal. With cast-iron frames the glazing, though of plate thickness, is much subject to cracking. Provision should also be made by means of condensation gutters or grooves for the removal of the moisture condensing on the underside of the glass. Wood sash bars with the glass bedded and puttied-in fre-

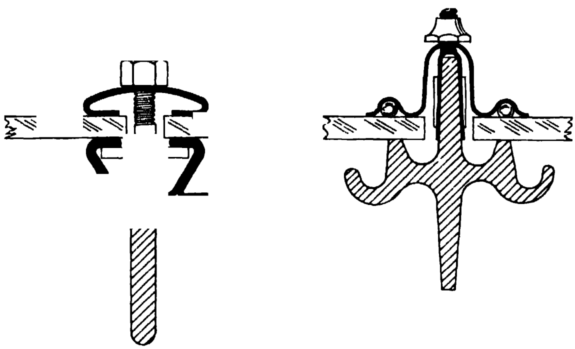

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FIG. 67. Rendle's patent 'Invincible' glazing bar.
FIG. 68. Helliwell's patent 'Perfection' glazing bar.

quently leak, and glazing in iron and steel bars of ⊥ section is likewise difficult to maintain in a watertight condition. Permanent watertightness is most easily reached by using patent glazing bars of suitable section (Figs. 67 and 68).

If skylights of zinc or galvanized steel are fixed the roof should be boarded and felted, for although the skylight itself is weather-proof a liability exists of water running back between the slates and the bedding plate.

Other details meriting close attention comprise the construction of a curb to lantern- and sky-lights and trapdoors which can be 'flashed' and thus made watertight at the junction with other roof coverings; apron flashings to lean-to lights; and hip and ridge coverings to lantern-lights. For such flashings, &c., either lead, copper, or zinc can be used.

Eaves, Eaves Gutters, and Rain-water Shoots and Pipes

Projecting eaves and verges afford considerable protection to the walls against rainfall, and in the case of thatched roofs, where gutters are not usual, constitute the sole protection for the walls against 'drip'. Flat roofs, parapet, and cornice gutters on old buildings are sometimes provided with shoots or spouts—maybe in the form of gargoyles—for discharging rain-water, but these are often responsible for splashing and dampness of the walls near to the ground.

Eaves gutters with down-pipes are the best preventative against drip and splashing.[1] Both gutters and pipes should be adequate in size so as to cope with heavy rainfall. Gutters must have sealed joints, and a sufficient fall —not less than 1 in. in 10 ft.—to the outlet. The joints of the down-pipes are seldom made so as to be watertight; in order, therefore, to prevent the soakage of water into the wall should a stoppage occur in the pipe and a leakage take place at any joint, the pipe can be fixed 1–2 in. clear of the wall by the use of ear wings with bands, holderbats, or ear blocks—a practice advisable in all circumstances. Pipes ought to be continued to the ground level and discharge direct into gully traps or shoes, or be fitted with shoes discharging horizontally away from the walls.

Remedies for Damp Walls

Dampness in existing walls due to the passage of moisture into and through the fabric from driving rains, by osmotic or capillary action, or direct permeation, may be remedied by the application of the methods described for new work, completely or in a modified form, or by other special treatment.

Horizontal damp course. The lack of a horizontal damp course in a brick wall can be dealt with by underpinning

[1] See Chapter III, p. 56.

the wall, i.e. cutting out 2–4 courses (according to the wall thickness) of brickwork in lengths not exceeding 3 ft. at a time and inserting a suitable damp course and then making good the wall. For stone and concrete walls where underpinning and the insertion of a damp course is difficult and maybe impracticable, rendering of the surfaces is advocated.

Treatment of exterior surfaces. The exposed exterior surfaces of brick, stone, and concrete walls may be faced with slates or tiles or rendered with waterproofed cement mortar as described for new work. Walls below ground with abutting soil may be similarly rendered with waterproofed cement mortar or mastic asphalt if excavation of the ground is practicable, such rendering being carried down and joined to a horizontal damp course as in Fig. 40. Slates or tiles below the surface of the ground are unsuitable. A coating of hot pitch is sometimes applied, but it is much inferior to either waterproofed cement or asphalt and is subject to deterioration by soil contact.

Dry areas. Alternatively, a dry area as illustrated by Figs. 36 and 37 may be formed, in which case both the wall of the building and the wall forming the area should be rendered, the latter to prevent the percolation of subsoil water into the area.

Treatment of interior surfaces. Remedial treatment is always best applied to the outer surface of the wall as the entry of moisture into the wall is thereby prevented. Where this is impracticable (a condition often obtaining with basements) treatment of the interior surface is necessary.

For mild cases of dampness the treatment may take the form of hacking off all old plaster and rendering the surface with waterproofed cement mortar to a thickness of 1 in. Where dampness is due to abutting soil against the wall and floor perviousness, the treatment may be wall rendering as above, and $\frac{3}{4}$–1 in. of waterproofed cement topping with trowelled finish on the existing or newly pro-

vided cement concrete floor, with a coved angle between wall and floor.

Should the ground be waterlogged, subject to flooding or water pressure, the walls should be rendered to a thickness of $1\frac{1}{4}$ in. in four coats, and the existing floor concrete covered with 6 to 9 in. of reinforced waterproofed concrete with a $\frac{3}{4}$-in. cement floating applied to the floor immediately the concrete is set and before it is dry, the floating being coved to walls as in Fig. 45.

Floors and walls can be effectually damp-proofed with mastic asphalt, Callender's bitumen sheeting, or other equally satisfactory material, but it is necessary to erect a thin brick or concrete wall in front of the vertical, and to lay a holding-down concrete floor on the horizontal, waterproofing material to prevent it being forced off by water pressure. Fig. 44 illustrates the mode of fixing. As an alternative, a cavity can be arranged between the wall to be treated and the new shell and filled in with 'Bitubond' or similar material.

The rendering in waterproofed cement mortar of the interior surfaces of walls is cheaper than the construction of a dry area and the insertion of a damp course, and may be regarded as satisfactory, provided always that the work is executed by skilled workmen giving strict adherence to the manufacturers' directions. For 'Pudloed' work the following hints are given and may be followed in using other cement renderings.

Prior to rendering walls, all paint, limewash, distemper, and plaster must be removed, the surface brushed down with a wire or strong fibre brush, and the brick- or stonework hacked or punched to form a good key. Cemented walls and floors should be well hacked and, if old, washed with a 10 per cent. solution of hydrochloric acid (spirits of salts) to increase the suction, the acid being thoroughly washed off before rendering takes place. The old work should be well wetted before the concrete or rendering is started. 'Killed' cement mortar should not be used. Con-

creting and each coat of rendering should be done in one operation, 'left' edges being chamfered 7 to 8 in. on the splay and coated with a neat cement slurry before resuming the work. No coat of rendering should exceed $\frac{3}{8}$ in. in thickness and the rendering or floating of walls and floor of the respective coatings should follow on as soon as the undercoating has set and before it is dry. To harden the concrete the surface should be kept damp for seven days with sand or sawdust soaked with water and during this period left undisturbed. Finished wall renderings should be kept moist for a similar period by gentle sprinklings of water.

Condensation readily takes place on cement surfaces, particularly if the cement is waterproofed. The interior surfaces of walls thus rendered should therefore be finished with a thin skimming of lime plaster (setting stuff) made of 3 parts of Buxton lime or chalk lime, 6 of washed sand, and 1 of Plaster of Paris.

The interior face of walls is sometimes lined with thin sheet lead or tinfoil paper, but these can only be regarded as inefficient expedients.

Paints and waterproofing solutions. For the external treatment of walls where rendering is undesirable it remains to select a coating which will make the surface impenetrable to moisture. Such coatings are either a paint providing a film or skin on the surface, or a solution which combines either mechanically or chemically, or both, with the building material. The former include preparations of metallic paint, oil, paraffin (sometimes dissolved in naphtha) and tar, and the latter various preparations of silica of potash or soda used alone or in combination with other substances. 'Skin' coatings of paint need frequent renewal and are not the equal of a solution which will combine with the material to which it is applied. Among a number of available solutions reference may be made to the following:

(*a*) *Szerelmey's Stone Liquid* is applicable to brick, stone, cement

stucco, and tiles. The composition is mechanical and not chemical in its action and consists of an evaporative solvent used as a medium for conveying non-mineral colloids to a depth varying from $\frac{1}{16}$ in. to $\frac{1}{2}$ in. according to the nature of the material being treated.

(*b*) *Browning's Solution* hardens and waterproofs brick, stone, cement, and tiles, sinking into porous substances and forming by both chemical and physical action an elastic and imperishable film impervious to moisture.

(*c*) *The Bath Stone Firms' 'Fluate'* is a silicate preparation for stone. It is applied as a coating and followed by an application of a solution of calcium chloride which combines with the silicate in the stone and produces a hard, insoluble, damp-resisting silicate of lime.

(*d*) '*Ironite*', '*Stonefortis*', and '*Wallfortis*' which have similar water-repelling characteristics to (*a*), (*b*), and (*c*).

These solutions are usually applied with a brush in the manner of limewashing, care being taken to work the solution well into all cracks and indents.

Whatever the medium employed for repelling moisture the face of the work must be suitably prepared. It must be clean and dry, brushed down to remove dust, loose particles and flaking material, all defective parts cut out and made good and all joints properly pointed. For pointing it is advantageous to use waterproofed cement mortar, the joints being first raked out to a depth of $1\frac{1}{2}$ in.

'*Slurrying*' *or* '*slushing*'. For exterior and interior brick, stone, and concrete surfaces where the finished appearance is not of importance a treatment intermediate between rendering and coating with a solution is applicable, viz. a slurry or slush of waterproofed cement. 'Super Cement' and 'Ironite' are suitable; the former in the proportion of 18 lb. cement to 1 gal. of water; and the latter 1 lb. of 'Ironite' to 3 lb. of cement with sufficient water to form a creamy paste or thick slush. Before applying with a brush the brick, stone, or concrete surface must be made as wet as possible. Two coats are required, and as the efficiency of the treatment depends upon the thorough

hydration of the cement, rapid drying should be prevented by wetting the cement, when set, from time to time with a fine spray. The treatment meets the need of particular cases, but cannot be regarded as the equal of rendering.

Dampness from Drains within Buildings

Basements subject to the infiltration of subsoil water through the walls or floor are sometimes provided with surface-water drains. If the inlets are untrapped a risk is involved of moist air passing from the drain into the building; if trapped, evaporation over a dry period may destroy the seal with similar consequences. In some instances the means of drainage is a sewage drain with a twofold risk of the emission of damp and offensive air. The remedy for such basements is to waterproof the building, so as to prevent infiltration, and abolish the drains.

Where a sump exists under a building for subsoil water to drain into, flooding may occur on a rise of the water level in the absence of an efficient automatic pump or lift. Another cause of dampness from a sump is the lack of a suitable watertight cover.

VII

SPECIAL HYGIENIC REQUIREMENTS: DWELLINGS

OF the hygienic requirements contained in statutes and by-laws controlling construction some are common to all buildings, while others have a definite and strictly limited application to buildings used for stated purposes. In addition, buildings put to particular uses are in many instances subject to special by-laws, rules, regulations, or suggestions of authorities who exercise control under statutory or financial powers. A brief reference may be made to requirements not elsewhere dealt with.

Habitations Generally

The operative provisions of the London Building Acts, 1894–1908, include the following requisitions:

1. *Height of habitable rooms*: 8 ft. 6 in. If wholly or partly in the roof, 8 ft. for not less than one-half of room area.
2. *Lighting and ventilation*:
   (*a*) *Habitable rooms*. Window opening direct into external air or into a conservatory with a minimum lighting area of $\frac{1}{10}$ of floor area and an opening for ventilation extending to 7 ft. above floor level of not less than $\frac{1}{20}$ of floor area.
   (*b*) *Habitable rooms wholly or partly in roof*. A dormer window having a minimum lighting area of $\frac{1}{12}$ of floor area and an opening for ventilation extending to 5 ft. above the floor level of not less than $\frac{1}{24}$ of floor area; or lantern light with opening for ventilation equal to $\frac{1}{20}$ of floor area.
   (*c*) *Staircases*:
   (i) In dwelling-houses—Ventilated by window or skylight opening direct into external air.
   (ii) Tenement houses occupied by more than two families—Ventilated by windows or skylights opening direct into external air on every story above the ground story, or otherwise adequately ventilated.

In the Model code[1] there is no limitation of the height of rooms, but many local authorities provide for this by by-law. Lighting is provided for in the code with a minimum window area of $\frac{1}{10}$ of floor area with opening equal to $\frac{1}{20}$ extending to top of window for ventilation. For rooms without a fireplace and flue an aperture or air shaft to the external air of at least 100 sq. in. is needed for ventilation.

The Modern 'Working-Class' Cottage Dwelling

It is difficult to deny that the clamant cry for housing accommodation during the past decade and the urge to meet the need have been fruitful in the permissive use of doubtful materials and methods of construction,[2] resulting in a lowering of the structural standard previously recognized and the likelihood of heavy maintenance charges.

On the other hand, it must be allowed that official control as engendered by grants and subsidies has tended towards the establishment of a minimum standard of fitness when regarded particularly from the viewpoint of light- and air-space around the building and the provision of necessities, such as suitable cooking arrangements, provision for the storage of food, bathing, washing, and sanitary fitments; and that the standardization effected by the provision of houses through a State-aided scheme has had the merit of furnishing a description of minimum

[1] Urban, Series IV, 1925.

[2] Under section 25 of the Housing, Town Planning, &c., Act, 1919, local authorities were empowered to relax their by-laws for a period of three years and consent to the erection of buildings conforming with regulations made by the Local Government Board, which left a wide discretion to the local authority as to choice of materials and methods of construction. (See Chapter III, p. 54.) The Housing Act, 1925, repealed this section and gave power to the Minister of Health to revoke existing by-laws and make new by-laws for borough, urban and rural districts where the former unreasonably impede the erection of buildings. In London the county council can, with the consent of the Minister, suspend, alter, or relax any enactment or by-law relating to buildings. Under section 99 of the 1925 Act housing schemes approved by the Minister of Health are exempted from the by-laws in force if the latter are inconsistent with the approved plans.

desiderata for the general guidance of those interested in the subject. Thus it has been laid down that:[1]

(1) An adequate distance between the houses should be secured irrespective of the width of the roadway, with a sufficient frontage, generally of not less than 20 ft. to the buildings to allow convenient planning, good lighting of all the parts, and the avoidance of back projections, together with, in urban districts, about 400 sq. yds. of land per house, e.g. plots having 25 ft. frontage and a depth of 144 ft.

(2) The self-contained two-story cottage type should generally be adopted, and each house ordinarily include a living-room, scullery, larder, fuel store, w.c., bath in separate chamber, and three bedrooms. Other types may have (*a*) a parlour and more than three bedrooms, and (*b*) only two bedrooms.

(3) The best aspect for the living-room is south-east and should never be northerly except when sunlight can be admitted at the other end of the room.

(4) The best aspect for the parlour is a westerly one.

(5) The bedrooms should be placed as far as possible on the more sunny side of the house; two at least provided with fireplaces and adequate ventilation furnished to those without. In every bedroom there should be one window of which the top is not less than 6 ft. 6 in. from the floor.

(6) *Desirable sizes for rooms*:

Living room	180 sq. ft.
Parlour	120 sq. ft.
No. 1 bedroom	150 sq. ft.
No. 2 bedroom	100 sq. ft.
No. 3 bedroom	70–100 sq. ft.
No. 4 bedroom	65 sq. ft.
Scullery	80 sq. ft.
(This may be reduced slightly where the washing is provided for in the bathroom or in a wash-house.)	
Larder for urban or suburban areas .	12–16 sq. ft.

Coal-store—Not less than 15 sq. ft.

Height of rooms to be 8 ft.

[1] *Manual on the preparation of State-aided Housing Schemes*, 1919. Local Government Board.

(7) The scullery sink should be placed under or near the window, which should preferably overlook the garden; the copper be fitted with a steam outlet; and a suitable area outside the back door of the house paved with cement or other impervious material.
(8) The bath should, where practicable, be in a separate compartment.
(9) Hot water should generally be provided to the sink and the bath.
(10) The larder should be on the northerly side of the house; where this is impracticable the window should be screened from the sun.
(11) The coal-store should generally be so placed that coal may be delivered from outside, and fetched for use under cover.
(12) The w.c. should be accessible under cover. In larger houses it may be on the first floor. Where there is an earth-closet it must be constructed outside the house.

Houses of this type are best if semi-detached. If in a group of four then a secondary means of approach to the rear is necessary in the centre of the block, unless otherwise provided for.

Typically planned 'parlour' and 'non-parlour' houses are shown in Figs. 69 and 70.

The Working-Class 'Flat' or 'Block' Dwelling

As intimated in Chapter II, p. 47, the scarcity of available land in city and crowded urban areas brings into prominence the necessity for buildings of three, four or more floors. In the plotting of these, site difficulties often rule out the possibility of providing as favourable an aspect as with two-story houses on relatively large areas. The best aspect should, however, be given, and in all circumstances the height or distance apart determined as suggested in Chapter II, p. 48, so as adequately to light the rooms on the various floors.

The dwelling should be self-contained, i.e. provided with sanitary and other conveniences for the sole use of the

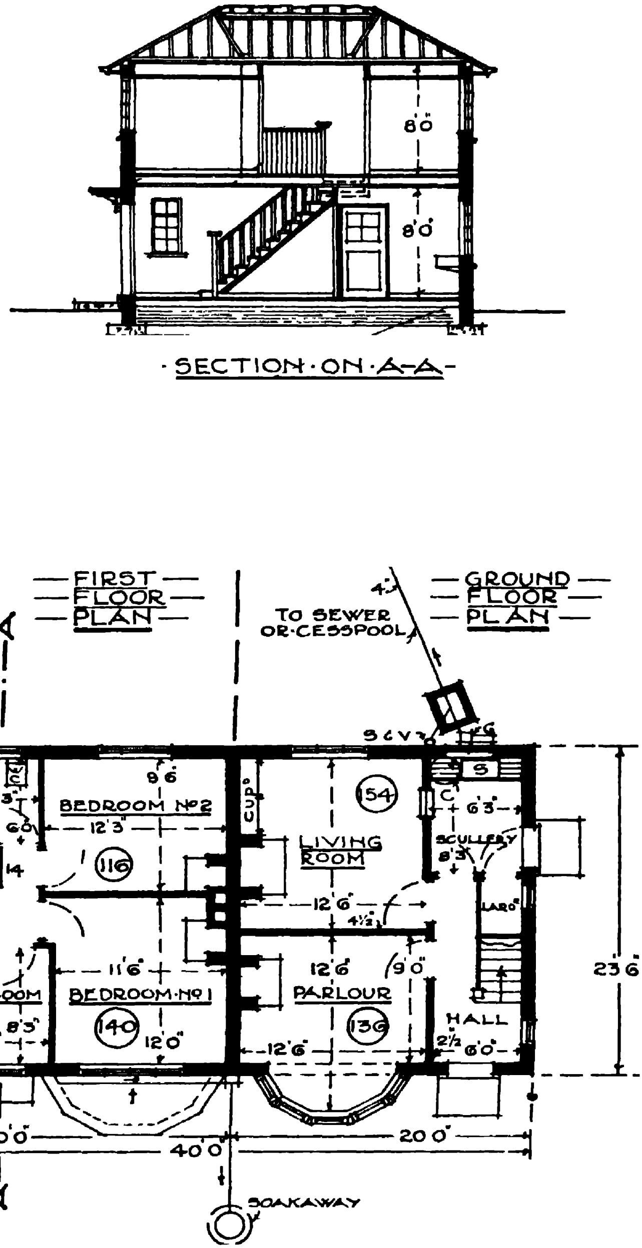


Fig. 69. Typical 'parlour' house (Ministry of Health type).

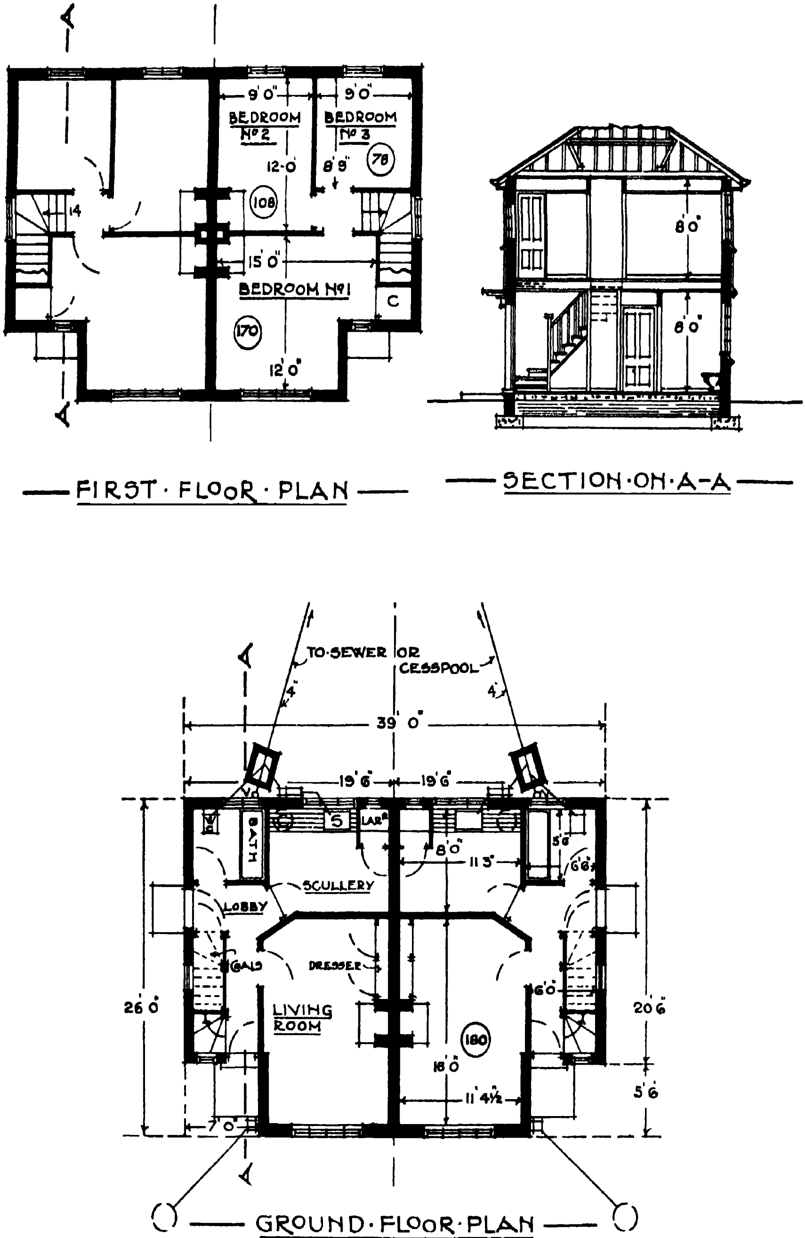


FIG. 70. Typical 'non-parlour' house (Ministry of Health type).

persons in occupation. In some schemes a wash-house suitably fitted with wash-tubs and a plentiful supply of hot water is convenient for use in common, but this provision is not always appreciated. The planning, size, and number of rooms vary with the class of persons to be

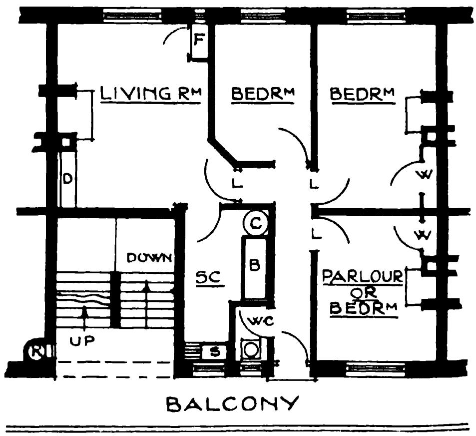


FIG. 71. Block dwellings. Tenement approached from balcony. B. Bath. C. Gas copper. D. Dresser. F. Food cupboard. L. Fanlight over door. R. Refuse shoot. S. Sink and draining-board. W. Wardrobe cupboard.

housed and the rents to be charged. The room sizes and the conveniences scheduled for cottage dwellings should here be regarded as the minimum.

Fig. 71 illustrates a part plan of a well-arranged block of dwellings with the entrances to the respective lettings direct from a balcony—an arrangement much in advance of the old type where the entrances are commonly direct from internal landings, often none too well lighted.

Tenement or 'Down-Town' Houses

A distinctive feature of many large cities is the trend of people who can afford it, or whose business permits, to move their residence outwards to the periphery or beyond, where more spacious surroundings are to be found—a trend due in no small degree to modern travel facilities.

The result of this migration is to leave vacant large houses originally built for one family and possessing conveniences suitable and sufficient for such only. Some of these houses are absorbed for commercial purposes by the spread of business from the centre and the natural development of local industries. In some districts the houses are converted into hotels and boarding-houses with such alterations and fitting up as the new owner or lessee may consider essential. In the main, however, individual properties of this kind fall into the hands of persons who let them out in floors or tenements of one, two, three, or more rooms, and this without any, or only the very slightest, attempt to convert and fit them as residences for several families.

Rooms originally designed as reception- or bed-rooms are let separately without conveniences for storing and cooking food, consequently food is stored in unventilated cupboards and elsewhere under most unsatisfactory conditions, and gas cooking stoves are fitted in bed- or living-rooms or on staircases, without adequate means for removing from the cooker unconsumed gas and the products of combustion, much to the detriment of the atmosphere of the rooms and house generally. Further, it is commonly found that all water needed for cooking, washing, and ablutions must be carried up several flights of stairs, and waste water carried down to the ground or basement level for disposal, at which levels the water-closet and sink are usually located.

In the central boroughs of London acres of property have thus descended in the social scale and form one of the most difficult sanitary and economic problems, relieved, in many instances, only when the leasehold interests fall to the ground landlord and redevelopment of the estate takes place.

The sanitary authority may require the improvement of such houses in particular details. Additional water-closets can be insisted upon if so be the accommodation is insuffi-

cient.[1] In London an extension of the water supply to upper floors can in certain cases be required, and provision made for storing and cooking food;[2] but no statutory power exists requiring the owner properly to convert and fit the houses to meet the sanitary and conventional needs arising from use by several families instead of one, unless they can be scheduled as houses let in lodgings, in which case they must comply with the by-laws (see later).

Admittedly, with houses suitable for occupation by persons of the working classes,[3] a duty falls upon the owner to 'make and keep such a house in all respects reasonably fit for human habitation',[4] and the authority can serve a notice to effect this and carry out works in default by the owner; who, however, is entitled to give a notice to the local authority to the effect that as the house cannot be rendered fit without reconstruction he will close it for human habitation. Such notice by the owner involves a decision by the Minister of Health that the house can be made fit for habitation without reconstruction before the local authority can execute the required works. The procedure in these cases is complicated, and a satisfactory result is difficult of attainment.

To permit of the conversion of a house into tenements a county court may vary the terms of a lease or other instrument imposing a prohibition or restriction against

[1] Public Health Act, 1875, Public Health (London) Act, 1891, and Housing Act, 1925. A by-law made under the Act of 1891 provides that the owner of any lodging-house (i.e. a house or part of a house let in lodgings or occupied by members of more than one family) shall provide and maintain water-closet, earth-closet, or privy accommodation in the proportion of not less than one convenience for every twelve inmates.

[2] London County Council (General Powers) Acts, 1907 and 1908. The powers given are not, however, retrospective.

[3] For the purposes of the Housing Act, 1925, "The expression "working class" includes mechanics, artisans, labourers, and others working for wages, hawkers, costermongers, persons not working for wages, but working at some trade or handicraft without employing others, except members of their own family, and persons other than domestic servants whose income in any case does not exceed an average of three pounds a week, and the families of any such persons who may be residing with them.'

[4] Housing Act, 1925.

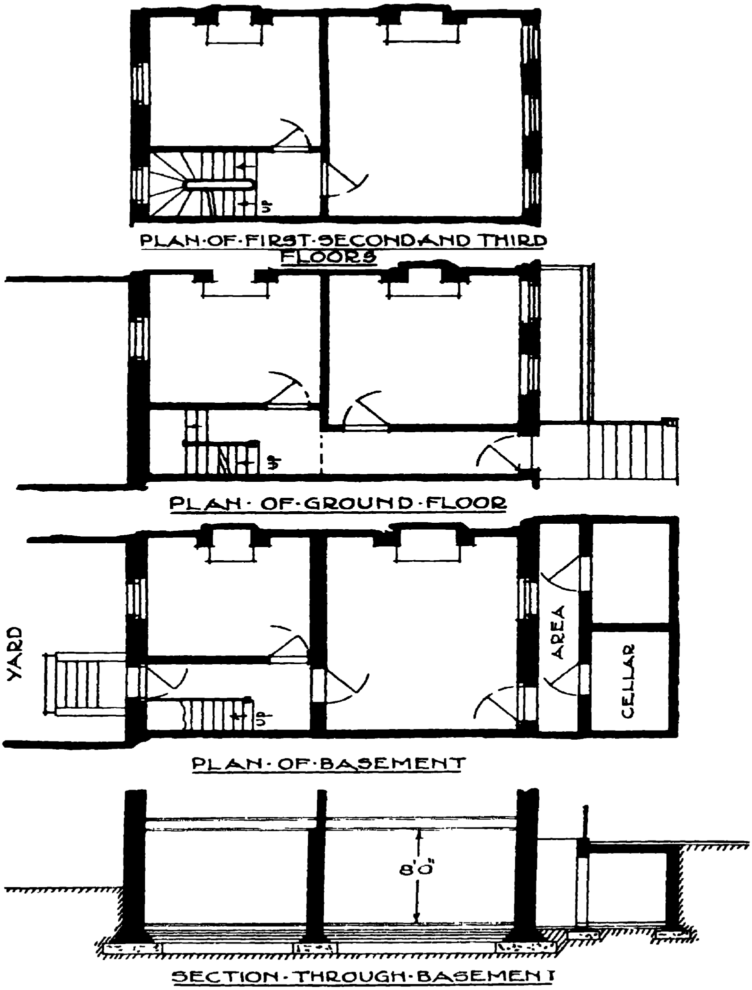


FIG. 72. Terrace house originally built for one family.

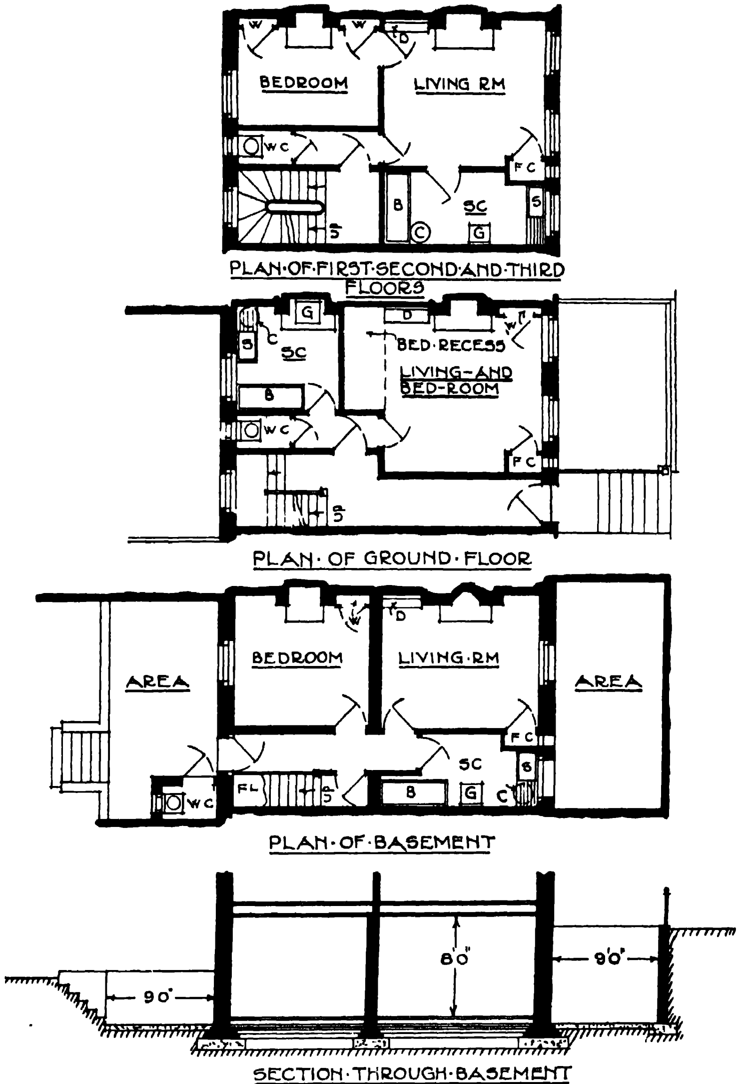


FIG. 73. Conversion of terrace house (Fig. 72). Ground floor into one-room; and basement, first, second, and third floors into two-room tenements. B. Bath. C. Copper. D. Dresser. G. Gas cooker. FC. Food cupboard. S. Sink and draining-board. SC. Scullery. W. Wardrobe cupboard.

such conversion; and legal steps may also be taken by a ground landlord to enable him to step in and carry out a scheme of reconstruction or improvement approved by a local authority.[1]

Houses let in tenements, whatever the social position of the occupants, ought to have suitable, sufficient, and accessible conveniences as adumbrated for cottage dwellings. Ideal conditions resulting from the conversion of houses of the kind under review cannot be expected, but salutary improvements can be effected and a reasonable standard of habitation obtained.

Fig. 72 shows a house of the terrace type, and Fig. 73 its conversion with the minimum of structural alteration.

Houses Let in Lodgings

By-laws controlling houses let in lodgings for the working classes[2] can be made and enforced by sanitary authorities outside London, and made by the County Council within London, the sanitary requirements in the latter instance being enforced by the borough councils.[3] The code applying to the metropolitan boroughs provides:

1. *Definition*[4]:

   'Lodging-house' means a house or part of a house intended or used for occupation by the working classes and let in lodgings or occupied by members of more than one family, but shall not include a house in which the tenant resides on the premises and in which not more than two persons in addition to the tenant and his family also reside at any one time.

2. *Duties of owner.* Every OWNER of a lodging-house shall:

   (*a*) Where it is necessary for the prevention or remedy of insanitary conditions that all or part of any court or courtyard of the lodging-house should be paved, forthwith cause the

[1] Housing Act, 1925.

[2] See footnote, page 123.

[3] Public Health Act, 1875; Public Health (London) Act, 1891; and Housing Act, 1925.

[4] *By-laws made with respect to houses divided into separate tenements, &c.*, 1926. London County Council.

These by-laws do not apply to the City of London. See also the Model by-laws relating to *Houses let in Lodgings*. Ministry of Health.

same to be properly paved with a hard, durable, and impervious pavement evenly and closely laid upon a sufficient bed of good concrete and so sloped to a properly constructed channel leading to a trapped gully grating as effectually to carry off all rain or waste water therefrom.

(*b*) At all times keep in good order and proper repair the pavement channel and grating.

(*c*) Provide and maintain for the use of each family by whom any part of the house is occupied, and so far as is practicable on the story or one of the stories, in which are situate the rooms or lodgings in the separate occupation of the family:

(i) Water-closet accommodation;

(ii) Accommodation for washing clothes;

(iii) Accommodation for the storage of food in a reasonably cool position with proper ventilation from the external air wherever practicable, and with protection from dust and flies;

(iv) Accommodation for the preparation and cooking of food;

and, where reasonably necessary, and so far as practicable, provide separate accommodation as specified in (i) (ii) (iii) and (iv) aforesaid for each such family.

(*d*) Keep every common staircase in the lodging-house in a state of good repair.

(*e*) Wherever practicable provide every common staircase in the lodging-house with adequate means of lighting by natural light, including in the case of a new building constructed for use as a lodging-house a window or windows with a total superficies clear of the sash frames of not less than 4 sq. ft. on the staircase at each story above the ground story opening directly into the external air.

(*f*) Provide adequate means for the artificial lighting of every common staircase.

(*g*) Provide and maintain:

(i) Every habitable room of the lodging-house with a window or windows opening directly into the external air and having where practicable a total area, exclusive of the sash frames, equal at the least to one-tenth of the floor area of the room and capable of being opened at the top to at least one-half of the extent of the window. (Note:—

This by-law does not apply to any case governed by the London Building Acts 2 (a) and (b), p. 115.)

(ii) In connexion with every tap from which water may be drawn, efficient means for carrying off any waste water from the tap.

(iii) Adequate means of ventilation for every passage, room, and staircase. (See note to (i).)

3. *Duties of tenant and lodger.* Divers responsibilities are placed upon every TENANT and LODGER to maintain in a cleanly condition the parts of the premises under their control.

4. *Generally.* A PERSON shall not cause or knowingly permit any room in a lodging-house wholly or partly used as a sleeping apartment to be occupied at any one time by a greater number of persons than will allow 400 cu. ft. of free air space for each person.[1]

Common Lodging-Houses

A common lodging-house within the meaning of the English Acts is generally accepted as 'that class of lodging-house in which persons of the poorer class are received for short periods, and, although strangers to one another, are allowed to inhabit one common room'.[2] For the keeping of a house a licence is obligatory in London, and registration in districts where the Public Health Act, 1875, applies. The buildings and conduct are regulated by by-laws made and applied by local sanitary authorities outside,[3] and by the County Council inside, London.[4]

The metropolitan code[5] amongst other requirements specifies that a room must not be used as a sleeping apartment if the floor is more than 3 ft. below the surface of the adjoining ground unless so used prior to the date when the by-laws came into operation, in which case the room

[1] Until six months after the expiration of the Rent and Mortgage (Restrictions) Acts, 1920 and 1923, the cubic space in a sleeping apartment to be 300 ft. for an adult and 150 for a child under 10 years; and 200 for a child in a room not exclusively used for sleeping.

[2] Logsdon v. Booth (1 Q.B. (1900) L.R. 412).

[3] Public Health Act, 1875.

[4] London County Council (General Powers) Act, 1902.

[5] *By-laws made by the London County Council . . . in respect of Common Lodging Houses within the County of London*, August, 1903.

must comply with the requirements relating to underground rooms ((*a*) to (*g*) and (*i*) to (*k*), p. 132); the provision of lavatory basins for ablutions; the maintenance of all parts of the premises in a good state; and all means of ventilation, flushing apparatus, &c., in efficient working order; periodic cleansing of the interior surfaces of all walls and ceilings (April and October); the removal of all refuse; and, generally, such cleansing as is necessary to maintain the premises in a clean and wholesome state and free from vermin.

In addition to these by-laws certain rules[1] are also applicable, including:

(*a*) In houses adapted after 12 March 1903, cubic space of not less than 350 ft. in any room and a floor space of at least 30 superficial ft. is to be allowed for each lodger.

(*b*) Houses accommodating lodgers of both sexes must be provided with separate kitchens, bedrooms, staircases, lavatories, yards, water-closets and other conveniences.

(*c*) Married couples' quarters must have distinct lavatory and water-closet accommodation for each sex.

(*d*) Dormitories must be arranged in such a manner that men, women, and married couples may sleep on different floors.

(*e*) Each cubicle for a married couple must have the whole or part of a window opening to the external air.

(*f*) The number of water-closets and lavatory basins is determined as follows:

WATER-CLOSETS

Houses accommodating	*Number of water-closets*
(i) Not more than 24 persons	1 for every 12 or part of 12 persons.
25–60 ,,	1 for every 15 or part of 15 persons.
61–100 ,,	1 for every 20 or part of 20 persons.
More than 100 ,,	1 for every 25 or part of 25 persons.

[1] *Statement for the information of applicants for licences, and of licensees, with respect to common lodging houses in the County of London, exclusive of the City of London*, 1922. London County Council.

Houses accommodating	*Number of water-closets*
(ii) Existing houses with fewer than 60 lodgers	1 for every 15 or part of 15 lodgers.

LAVATORY BASINS

Houses accommodating	*Number of basins*
Not more than 150 persons	1 for every 10 or part of 10 persons.
150–400 ,,	1 for every 15 or part of 15 persons.

(*g*) If lodgers of both sexes are accommodated, water-closets and washing accommodation to be provided for each sex in accordance with the foregoing tables.

(*h*) Lavatory basins must be fixed in a slate slab.

The social status of lodgers in these houses suggests an ever-present risk of verminous conditions, and this should be borne in mind in the fitting up of the various parts of the premises. Floors of kitchens, dormitories, passages, &c., should be jointless or covered with a hard-surfaced linoleum, the internal angles of walls and floors coved, walls finished with an oil paint, and wood mouldings and other finishings affording harbourage for vermin dispensed with. A plentiful supply of hot water is also desirable. For buildings housing a large number of persons a drying stove for clothes and a fumigation room are useful adjuncts. Slipper and foot baths and washtubs are much appreciated. One foot bath to 100 persons is about the number required, and these are best fitted with teak seat boards.

If cubicles are provided, a window in the external wall of each is requisite. Partitions separating the cubicles should either be of smooth and impervious material or of close-jointed wood framing coated with paint enamel, fitted so as to leave a space of 6 in. between bottom of partition and floor and with sufficient space between top of partition and ceiling for ventilation; due regard, of course, being paid to a height to afford privacy. Fig. 74

is a part plan of one floor of a common lodging-house, and shows the general arrangement of cubicles and sanitary fitments.

Seamen's Lodging-Houses

The Merchant Shipping Act, 1894, entitles local authorities to make by-laws with regard to seamen's lodging-houses, including licensing.

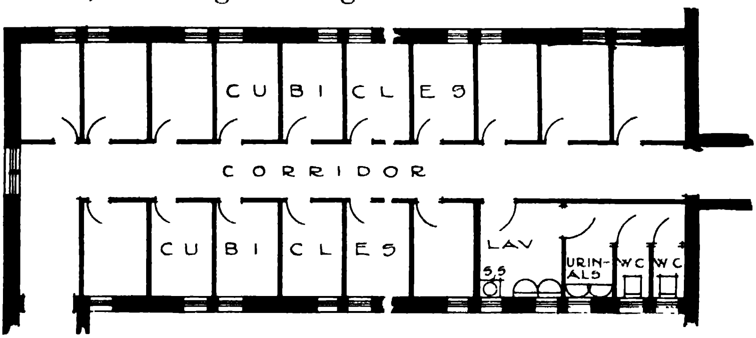


FIG. 74. Plan showing arrangement of cubicles for a man's hostel or common lodging-house.

The licensing and supervisory authority for the administrative county of London is the County Council. The by-laws[1] provide that:

(*a*) A 'seaman' means any male person other than the holder of a certificate of competency or service as master, mate, or engineer, in the merchant service who is ordinarily employed in any capacity whatsoever on board ship.

(*b*) A sleeping apartment must have at least 400 cu. ft. of free air space per occupant; a kitchen, scullery, or sitting-room, or an underground room failing to comply with the provisions set out below must not be used as a sleeping apartment; water-closet accommodation must be provided on a scale identical with that applying to common lodging-houses (i) (p. 129); a sufficient number of washing basins with water supply must be provided; and the premises and fitments generally maintained in good order and in a clean state.

[1] *By-laws made by the London County Council in pursuance of section* 214 *of the Merchant Shipping Act,* 1894, *relating to seamen's lodging houses in the Administrative County of London,* 1917.

A great diversity is seen between these lodging-houses and the class of seamen using them. Many houses are of the 'furnished-lodging' type, while others more nearly approximate to common lodging-houses, so it is not easy to lay down a common rule as to the fitting up and provision of ordinary essentials.

Underground Rooms or Cellar Dwellings

In London [1] an underground room includes any room of a house where 'the surface of the floor . . . is more than 3 ft. below the surface of the footway of the adjoining street, or of the ground adjoining or nearest to the room', (Fig. 75), and it is an offence to let or occupy separately any such room if not so let or occupied before 1892 unless it possesses the following requisites:

(*a*) A minimum height of 7 ft. with 3 ft. of the height above the level of the adjacent ground.
(*b*) An open area 4 ft. wide with paved surface 6 in. below level of room; with the proviso that if the width of the area is not less than the height of the room from the floor to the surface of the adjacent ground, the height of the room above the ground level may be less than 3 ft. but not less than 1 ft., and that the area need not in any case be more than 6 ft. wide (Fig. 75).
(*c*) A proper damp course and protection against dampness from the soil in contact with the walls.
(*d*) Drainage of area and soil below room.
(*e*) Ventilation of floor, if hollow.
(*f*) A gas-tight drain.
(*g*) Protection against the rising of effluvia or exhalation.
(*h*) A water-closet and ashpit.
(*i*) Effectual ventilation.
(*j*) A fireplace with chimney or flue.
(*k*) A window equal to one-tenth of the floor area with top-half made to open.

If so be an underground room was let or separately occupied prior to 1892, it may continue to be so let or

[1] Public Health (London) Act, 1891.

occupied with the consent of the sanitary authority, who is empowered to dispense with or modify—either absolutely or for a limited time—any of the above-mentioned requisites involving structural alteration, provided the room conforms to the requirements contained in the Metropolis Management Act, 1855, and in force before 1892, viz.:

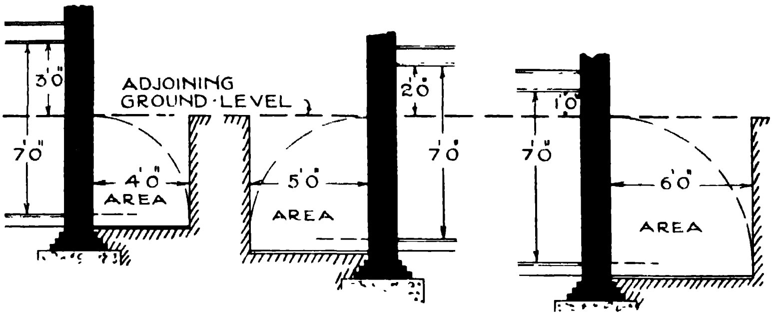


FIG. 75. Underground rooms (London). Minimum height of room, height above adjoining ground surface, and width of area.

(*a*) A minimum height of 7 ft. with 1 ft. above the nearest ground.
(*b*) An area 3 ft. wide.
(*c*) Effectual drainage of room.
(*d*) Protection against effluvia from sewer or drain.
(*e*) A water-closet and ashpit.
(*f*) A fireplace with proper chimney or flue.
(*g*) A window with a minimum area of 9 super ft. made to open in an approved manner.

Comparing the requirements of the two Acts it would appear that the only modifications in the power of the sanitary authority are acceptance of a room 7 ft. in height with 1 ft. above the nearest ground, and an area 3 ft. in width (1855) in place of one 4 ft. in width (1891).

Outside London legal occupation of cellar dwellings is confined to rooms separately occupied in 1848 and having[1]:

(*a*) A room height of 7 ft. with 3 ft. of its height above the surface of the street or ground adjoining or nearest thereto.

[1] Public Health Act, 1875.

(*b*) An open area 2 ft. 6 in. in width.
(*c*) An effectual drain.
(*d*) A water-closet, earth-closet, or privy, and an ashpit.
(*e*) A fireplace with chimney or flue.
(*f*) A window at least 9 super ft. in area for a front cellar and 4 ft. for a back cellar jointly occupied.

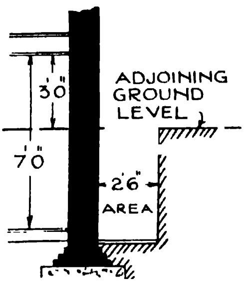


FIG. 76. Cellar dwellings (extra-Metropolitan areas). Minimum height of room, height above adjoining ground surface, and width of area.

Fig. 76 illustrates minimum height of room and width of area.

It must be definitely understood, both as regards London and extra-metropolitan districts, that the basis of offence is 'separate' occupation. If occupied with a room on the same or any other floor which is not technically an underground room or cellar dwelling, the occupation is legal.

The Housing Act, 1925, prescribes that a room habitually used as a sleeping place the surface of the floor of which is more than 3 ft. below the surface of the part of the street adjoining or nearest to the room, or more than 3 ft. below the surface of any ground within 9 ft. of the room, shall . . . be deemed to be a dwelling-house so dangerous or injurious to health as to be unfit for human habitation, if the room:

(*a*) Is not on an average at least 7 ft. in height from floor to ceiling; or
(*b*) Does not comply with the regulations of the local authority (or the Minister of Health) made for securing proper ventilation, lighting and protection against dampness, effluvia or exhalation.

The apparent effect of this prescription is to bar the use of a room for 'sleeping' unless it is 7 ft. high and complies with the regulations; but there is nothing to prevent its use for other domestic purposes, such as a 'living' room.

None of the legal requirements cover underground rooms used for purposes other than those just mentioned, with the single exception of bakehouses;[1] hence, rooms barred from separate occupation as dwellings may be utilized for offices, workshops, &c.

Many hygienically unfit basements can be improved so as reasonably to fit them for domestic or commercial use. Such matters as prevention of dampness, drainage, floor ventilation, protection against soil exhalations, and the provision of a water-closet and ashpit are matters open to compliance. Enlargement of the window area and the provision of effectual ventilation are often practicable. The insuperable difficulties generally are the height of the room and the width of the area; but if the height conforms with the permissible minimum it is possible sometimes to enlarge the area so as to meet the requirements.

Stable Dwellings

Atmospheric disconnexion of a stable from a dwelling over should be assured. The London Building Acts[2] require every part of a floor not occupied by a joist or girder to be solid or have a pugging of 3 in. of concrete finished smooth on the upper surface and ceiled on the underside. Any approach to the dwelling must be separated from the stable by a brick wall not less than 9 in. in thickness.

Tents, Vans, Sheds, and Similar Structures

These, if used for human habitation, can be regulated by by-laws.[3] If in such a state or so overcrowded as to be a nuisance or injurious to health the structure can be dealt with summarily as a nuisance.

[1] See Chapter IX, p. 163.
[2] 1894–1908.
[3] Housing of the Working Classes Act, 1885; Public Health (London) Act, 1891; and Public Health Act, 1925.

The Model by-laws,[1] amongst other requirements, prescribe:

(*a*) Provision of:

(i) Adequate means of permanent ventilation.

(ii) A suitable dry flooring or other dry covering.

(iii) A sufficient supply of wholesome water and a water storage receptacle.

(iv) A receptacle for refuse.

(v) Privy accommodation where nuisance from the want of it is likely to arise.

(*b*) Maintenance of the structure in a reasonably weather-proof state, and the internal surface and floor in a cleanly condition.

(*c*) A prohibition against the keeping of animals and the deposit of filth within 40 ft. of any drinking-water source.

Habitations for Hop-Pickers and Pickers of Fruit and Vegetables

The Council of any borough or urban or rural district may make by-laws for securing the decent lodging of persons engaged in these occupations.[2] The Model code provides[3] that such habitations shall be:

(*a*) Constructed and maintained so as to be clean, dry, and weather-proof, properly ventilated and sufficiently lighted.

(*b*) Provided with:

(i) 16 sq. ft. of floor space per person sleeping therein (two children under 10 to count as one person).

(ii) Separate sleeping apartments for adult persons of different sexes—adult person to mean one exceeding the age of 12 years, except where room is appropriated to a single family, i.e. husband, wife, and children not exceeding 14 years.

(iii) A cooking-house for cooking food and drying clothes, &c., on the basis of one fireplace for every 15 persons.

(iv) A supply of good and wholesome water.

[1] Model by-laws,—*Tents, Vans, Sheds, and Similar Structures*, 1926. Ministry of Health.

[2] Public Health Act, 1875, and Public Health (Fruit Pickers' Lodgings) Act, 1882.

[3] *Hop-pickers and Pickers of Fruit and Vegetables*, 1910. Ministry of Health.

(v) A sufficient number of water-closets, earth-closets, or privies constructed in a suitable position for the separate use of each sex.

(vi) A sufficient supply of clean, dry straw or other suitable bedding—changed or cleansed from time to time.

(*c*) Kept free from accumulations of filth, and the interior surface of walls and ceilings limewashed at least once a year.

VIII

SPECIAL HYGIENIC REQUIREMENTS: SCHOOLS

THE chief matters calling for careful review in establishing 'a proper standard of health and sanitation' in schools were epitomized in 1926 by the Chief Medical Officer of the Board of Education as[1]:

(1) The school must be in a good state of repair, free from dampness and other gross defects and thoroughly sanitary.

(2) There should be an adequate water supply.

(3) There should be means for the adequate lighting, heating, and ventilating of the school and these means should be fully used. Wherever possible there should be cross-ventilation.

(4) Clean and wholesome cloakrooms and washing accommodation are necessary.

(5) The sanitary conveniences must be decent, healthy, and effective. They must be properly used and supervised.

(6) Suitable desks should be provided.

(7) It is not sufficient merely to provide space for a playground. The playground should be such as can be used not only for games and recreation but for physical training.

Without these things it is idle to talk about education in personal or public health.

Towards the attainment of such a standard the Board of Education by issuing and enforcing codes of building regulations have effected the betterment of existing schools and done much to establish an improved régime in respect of new premises. The departmental requirements include the following:

ELEMENTARY SCHOOLS[2]

1. *Playground*

The playground should:

(*a*) Be given a warm, sunny aspect.

[1] *The Health of the School Child*. Annual Report of the Chief Medical Officer of the Board of Education for the year 1925.

[2] *Building Regulations for Public Elementary Schools*, 1914. Board of Education.

(*b*) Be properly levelled, drained, and provided with a suitable surface.

(*c*) Provide sufficient space paved, concreted, or otherwise finished with a hard dry surface suitable for physical exercises in wet weather.

2. *General Arrangement*

The general arrangement of the building should be governed by the endeavour to secure a suitable aspect and effective ventilation for the class-rooms.

(*a*) Where a hall is to be provided, the class-rooms should not open directly from it. If they do, it is difficult if not impossible to get free cross-ventilation for them.

(*b*) Desirable to place the hall so that noise in it will not disturb the work in the class-rooms. For this reason, as well as for ventilation and freedom from dust, it may therefore be altogether or partly detached from the main building.

(*c*) The need for really effective ventilation and the importance of securing abundant sunlight are now generally recognized. The older type of building, compactly planned with several stories, with a central hall off which the class-rooms open directly, is giving place to single-storied groups of rooms, arranged to let the sun and air into every corner.

(*d*) The Board are prepared to consider plans showing class-rooms so arranged that one or more of their sides can be thrown completely open.

3. *Lighting of Class-rooms*

(*a*) Area of window-glass approximately one-fifth of the area of the floor-space.

(*b*) Windows so distributed as to light every table or desk and the whole of the room evenly and sufficiently. The last vertical glass line of the window farthest from the teacher on a line with the back of the last row of desks.

(*c*) Where windows are provided in one wall only, this must be the wall on the left of the scholars as seated. Any additional windows placed in the right-hand wall, but not so as to throw a stronger light from the right of the scholars than from the left. Windows facing either the scholars or the teacher are to be avoided. Skylights cannot be approved in 'main-rooms' or class-rooms except in special circumstances.

(*d*) Unless the top of the window be more than 12 ft. above the floor, no desk more than 20 ft. from a window.

(*e*) The lower glass line of the main lighting windows not more than 3 ft. 6 in. above the floor. Tops of the windows, as a rule, to reach nearly to the ceiling.

(*f*) French casements may be approved for some rooms.

(*g*) Clear glass should be used, and all kinds of glazing which diminish the light and are troublesome to keep clean and in repair avoided.

(*h*) Upper panels of the doors may be glazed with clear glass.

(*i*) Colouring of the walls and ceilings and of all fittings in the rooms should be carefully considered as affecting the light.

4. *Protection from Sun*

(*a*) Windows which face the sun should have blinds.

5. *Ventilation and Heating*

Windows of the ordinary type on one side of the room only, with some form of extract in the chimney or ceiling, and inlet tubes in the walls, can no longer be considered as providing the best form of ventilation for a class-room. Far more satisfactory results can be obtained by placing windows on opposite sides of the rooms, and so ensuring a fresh current of air. Experience has shown that if these windows are so arranged as to introduce the incoming air on a low level and to direct it upwards, and if a really adequate amount of heating is provided, an abundant supply of fresh air can be admitted all the year round. The heating surface will have to be increased above that required in the older type of rooms.

(*a*) The hall must be fully lighted, warmed, and ventilated.

(*b*) Adequate means for ventilating all rooms used for teaching must be provided, not only for admitting fresh air during use, but for flushing the rooms effectually during the intervals.

(*c*) Inlets for fresh air large, well-distributed, and provided with some arrangement to divert the incoming air from striking directly on to the children and teachers.

(*d*) In order to ensure a sufficient movement of the air, there should be openings on opposite sides of the room into the outside air.

(*e*) Where the rooms are properly cross-ventilated, ceiling extracts will not be required.

(*f*) One of various economical and effective plans is to have the lower panes of the windows arranged to open inwards as

'hopper' inlets with side pieces. The windows should be arranged so that at least half their area can be open at once. They may be arranged so that the whole space can be open.

(*g*) Openings behind hot-water radiators, and ventilating grates, are useful adjuncts in cold weather, but do not obviate the need for an ample supply of properly constructed opening windows.

(*h*) Combined systems of heating and ventilation in which air raised to a sufficient degree to warm the rooms is used for ventilation are not generally desirable in a school. The stimulating and invigorating effects of fresh, cool air are lost, and the children become accustomed to sit with closed windows.

(*i*) In buildings of more than one story the ventilation requires particular attention.

(*j*) As far as possible, long trunks and flues for the admission of air, which are difficult to keep clean, should be avoided.

(*k*) Outlets opening into chimney flues or ceiling ventilators do not work well without some mechanical aid.

(*l*) Generally, the best results will be obtained by providing ample heating power, and making full use of well-arranged windows to secure cross-ventilation.

(*m*) The heat supplied should be moderate and evenly distributed, so as to maintain a temperature of from 56° to 60° in the rooms; and the amount of heating required considered carefully in reference to the system of ventilation proposed, for the full use of fresh air openings is largely governed by the power of quickly warming the room. Where cross-ventilation is provided a single fireplace will be insufficient to warm the room thoroughly. Where windows are provided on two sides of a room, 25 to 30 sq. ft. of heating surface per 1,000 cu. ft. should be secured, and in a large room heated by an open fire, the heating should be supplemented by hot-water pipes on the side furthest from the the fire.

(*n*) When the heating is by means of hot water, it should be at medium or low pressure; high-pressure water and steam heating cannot be approved.

(*o*) Fireplaces and heating apparatus should as far as possible be placed in parts of the room where they will be out of the way of the teachers and scholars.

(*p*) Slow combustion stoves with long flue-pipes cannot be approved.

(*q*) Stoves of a pattern with an open fire, with proper chimneys into which the flue-pipe can be directly taken.

(*r*) Gas radiators or stoves are not approved for warming rooms used for teaching unless they are provided with flues.

6. *Floor-space*

(*a*) *Hall*—A floor-space of about 3½ sq. ft. for each scholar of the number for which the school is recognized, provided that its area should not exceed 1,500 sq. ft., except where provided for the joint or alternate use at separate times of two Departments of older children.

(*b*) *Class-rooms.*

(i) Not less than 10 sq. ft. of floor-space per scholar.

(ii) Long narrow rooms to be avoided.

(iii) A clear space extending the full width of the room of not less than 7 ft. 6 in. in depth should be left for the teacher; 1 ft. of space between the last row of desks and the wall; and a gangway of not less than 1 ft. 4 in. on one side of each child.

7. *Height of Class-Rooms*

(*a*) The height not less than 12 ft. if the room has a flat ceiling. If ceiled at the collar beam, 10 ft. to the wall-plate and 13 ft. to the ceiling. The ceiling should extend over at least half the area of the room. In no case may a class-room be left open to the ridge.

(*b*) In class-rooms arranged with corresponding windows on opposite sides these heights may be diminished by 1 ft., subject to adequate cross-ventilation.

8. *Class-rooms for Practical Work*

(*a*) Well lighted and provide not less than 15 sq. ft. of floor-space for each scholar.

9. *Handicraft Rooms or Centres*

In its plan, arrangements, lighting, and ventilation a room for teaching Handicraft should be modelled on a workshop rather than on a School.

(*a*) Height at the windows in front of the benches need not be more than 9 ft.

(*b*) Lighting and ventilation must be ample.

(*c*) Room should be warmed but need not be so warm as an ordinary class-room in which the children sit still.

(*d*) A room for 20 scholars should have a floor-space of at least 600 sq. ft.

(*e*) Unless part of the premises of a school, be provided with cloak-rooms and offices.

10. *Rooms or Centres for Domestic Subjects*

(1) *Domestic subjects*:

(*a*) Centres to have their own lavatories and cloak-rooms.

(2) *Cookery*:

(*a*) Capable of accommodating 18 scholars at practical work.

(*b*) At least 25 sq. ft. of clear floor-space for each scholar under instruction at one time; and, in addition, space for fixed apparatus, which should be reckoned roughly at about 5 sq. ft. per head.

(*c*) A north aspect is desirable; with special arrangements for ventilating, and, where necessary, for warming the room.

(*d*) Room so placed that smells from cooking will not penetrate into other parts of the school.

(*e*) A larder provided, with window facing north or east.

(*f*) Where gas is available, a gas-stove with flue-pipe to carry off fumes from the oven should be fixed in a convenient position.

(*g*) At least one sink, not less than 3 ft. in length, with draining-boards, and hot and cold water laid on.

(3) *Laundry Work*:

(*a*) A Laundry room or Centre should be capable of accommodating 18 scholars at practical work. (See 10. (2) (*b*) above.)

(*b*) Special arrangements for ventilating and, where necessary, for warming the room.

(*c*) A copper holding from 12 to 18 gallons is essential, with a water-supply tap and a tap for emptying it.

(*d*) Washing troughs are not required; two sinks, not less than 3 ft. in length, with draining boards, and hot and cold water laid on, are desirable; together with a slop sink, 12 in. deep, with a cold water tap above.

11. *Rooms for Advanced Drawing*

(*a*) A floor-space of 30 sq. ft. per scholar.

(*b*) A north light is desirable.

12. *Science Rooms*

(*a*) Between 20 and 25 sq. ft. of floor-space for each scholar; with water and gas laid on in suitable positions.

13. *Rooms for Younger Children*

(*a*) Room or rooms on the ground floor, with easy access to playground and offices.

(*b*) At least 9 sq. ft. of floor-space per head. In cases where a Junior department retains the children beyond the age of seven the Board may require some of the rooms to be reckoned on the 10 sq. ft. basis.

(*c*) An open fire, with room maintained at a temperature of about sixty degrees.

14. *Teachers' Rooms*

(*a*) Cloak-rooms, lavatories, and closets are required. For women these must be placed inside the main building. Where women are employed for the lower classes of Boys' departments, suitable lavatories and closets must be provided for them in the building. Closets should not open out of the rooms.

15. *Rooms for Meals (Children)*

A structure of the simplest kind, well ventilated, will suffice.

(*a*) Rooms of sufficient size to seat each child comfortably and to give space for waiting.

(*b*) A kitchen to provide 100 meals per diem should not have less than 200 sq. ft. of floor-space.

16. *Rooms for School Medical Officer*

(*a*) Room for the actual work of inspection, with a space of 20 ft. in one direction for eye testing.

(*b*) A small waiting-room, and a lavatory and water-closet conveniently placed.

17. *Cloak-rooms*

(*a*) Separate for each sex.

(*b*) Not passages; cut off from rooms used for teaching, and placed conveniently near the entrances.

(*c*) Amply lighted from the end.

(*d*) Separate means of ingress and egress.

(*e*) Floors of asphalt or other impervious material, and the walls lined to a height of about 5 ft. with glazed brick, matchboarding, or other suitable material.

(*f*) Through ventilation and disconnexion essential, so that smells are not carried into the school.

(*g*) Rooms warmed and, when possible, arrangements made for drying wet clothes.

18. *Lavatories*

(*a*) Lavatory basins at the rate of two for every fifty children with an equivalent allowance if troughs with sprays are used.

(*b*) A tap for drawing water should be provided. (No. 17 also applies.)

19. *Caretaker's Cupboards, &c.*

A slop sink and water-tap are desirable. Heating chambers should be properly ventilated.

20. *Closets and Urinals*

(*a*) Every closet must be not less in the clear than 2 ft. 3 in. wide, nor more than 3 ft., fully lighted and ventilated, and have a door at least 3 in. short at the bottom, and 6 in. short at the top. More than one seat cannot be allowed in any closet.

(*b*) The following table shows approximately the number needed:

Scheduled accommodation	*Water-closets.* *Girls.*	*Water-closets.* *Boys (In addition to urinals).*
Under 30 children	3	1
" 50 "	4	2
" 70 "	5	2
" 100 "	6	3
" 150 "	8	3
" 200 "	10	4
" 300 "	14	5
" 400 "	18	6

(*c*) If a block of offices is provided common to younger children of both sexes, there must be urinals for the younger boys, which with their closets must be partitioned off from the closets provided for the younger girls. If the number of children in the school is not large, a block of offices common to older girls and younger children can be approved; a proper proportion of the closets must then be made of a suitable height for children under eight years old.

(*d*) Urinals divided off from the closets and in the proportion of 10 ft. per 100 boys.

(*e*) Earth-closets of an approved type may be employed in country districts, but drains for the disposal of slop and surface water from the school will still be necessary.

(See also Chapters XI, p. 190; XVIII, p. 326; and XII, p. 398.)

21. *Baths*

(*a*) The Board will consider a proposal for the installation of shower baths or spray baths of a simple and effective kind where difficulty arises in providing facilities for cleansing children otherwise, and be prepared to accept the provision of such baths in substitution for a portion of the lavatory accommodation required. Such baths should provide for the bathing of 12 to 20 children at one time, have simple dressing boxes or partitioned spaces, and a drying chamber and storage for towels.

(The value of the shower, douche, or spray bath is recognized, 'not only as a means of cleansing a dirty child, but as a means of education and the inculcation of habits of cleanliness'. Direct physical benefit is derived by the children and increased ability to profit by the education they receive. The number of baths can be determined on the basis that a batch of 20 children can be bathed in 30 minutes—*vide* 'Annual Report for 1912 of the Chief Medical Officer of the Board of Education', pp. 40–2.)

22. *Water Supply*

(*a*) An adequate supply of wholesome drinking water readily available, but not placed within the enclosure of the closets.

(*b*) Where not taken from the mains of an Authority or Company authorized to supply water, care must be taken to ascertain (i) that the supply will be sufficient and (ii) that the water will be of suitable character and not liable to pollution in any way, as, e.g. by surface drainage, or by leakage from sewers, drains, cesspools, or other receptacles.

(*c*) No direct communication between any pipe or cistern from which water is drawn for domestic purposes and any water-closet or urinal.

(*d*) Cistern for the storage of water to be watertight, properly covered and ventilated, and placed in such a position that the interior may be readily inspected and cleansed.

(*e*) Water-pipes to be so laid or fixed as to be properly protected from frost, and so that in the event of their becoming unsound the water conveyed in them will not be liable to be fouled.

(*f*) All water-closets and urinals should be provided with proper service cisterns, which, together with the outlets from them, must be capable of providing a sufficient flush.

23. *Drainage and Sewage Disposal*

Compliance is required with a memorandum issued by the Minister of Health,[1] which, *inter alia*, provides:

(1) Drainage and closet arrangements to be planned on the general lines embodied in the Model by-laws.[2]

(2) Provision to be made for the disposal and removal of the following matters:

(i) Excremental matters.

(ii) Ashes and other dry refuse.

(iii) Waste water, as from lavatories and floor washing.

(iv) Surface water from roofs, yards, &c.

To meet (2) (i), (iii), and (iv) it is laid down that:

(*a*) Where an efficient system of public sewers and a constant water supply under pressure are available water-closets should be provided and their contents conveyed into the public sewers by drains, which should also receive the liquid waste from urinals, lavatories, and sinks, and where permitted, the surface water.

Water-closets should be of a suitable and efficient type, with adequate separate flushing arrangements for each closet.

(*b*) Where a water supply for flushing is available but there are no sewers, if water-closets are adopted they should be drained into a watertight tank with an overflow discharging on to an efficient filter or a suitable area of land for irrigation, or into a watertight cesspool without overflow, which should be so arranged that the contents can be readily removed by means of a suitable pump into a tank-cart, or by some other efficient method.

[1] '*Memorandum by the Local Government Board* (now the Minister of Health) *on the arrangements for DRAINAGE and disposal of waste matters at public elementary schools for which loans under the Board's* (Minister's) *sanction are required, with especial reference to schools in country places where sewers and water services are not available.*'

[2] Urban, Series IV, 1925; Rural, Series IVa, 1924; and Intermediate, Series IVc, 1924. Section 3 of the Education (Administrative Provisions) Act, 1911, provides as follows:

'The provisions of any by-laws made by any local authority under section 157 of the Public Health Act, 1875, as amended by any other Act, with respect to new buildings (including provisions as to the giving of notices and deposit of plans and sections), and any provisions in any local Act dealing with the construction of new buildings, and any by-laws made with respect to new buildings under any local Act, shall not apply in the case of any new buildings being school premises to be erected, or erected according to plans which are under any regulations relating to the payment of grants required to be, and have been, approved by the Board of Education.'

In no case can disposal of sewage by subsoil irrigation or any system of leakage into the subsoil or by its discharge untreated into a ditch or watercourse be regarded as satisfactory.

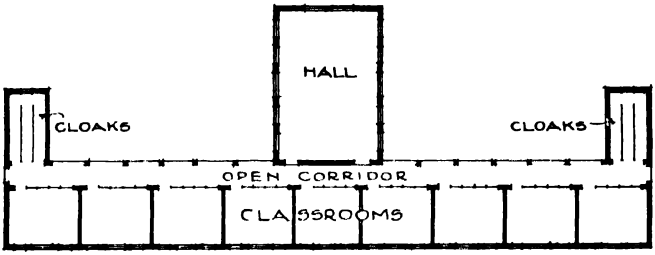


Fig. 77. Plan of 'pavilion' type school.

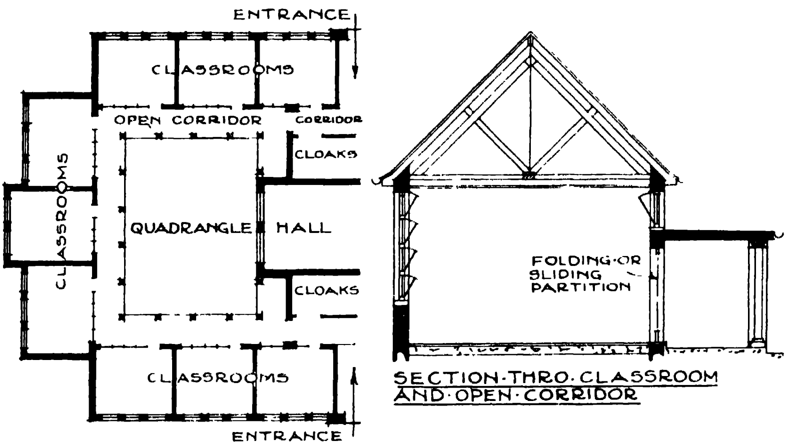


Fig. 78. Part plan of 'pavilion' type school with quadrangle, and enlarged section through class-room.

(*c*) Where sewers are available but no supply of water is laid on for flushing, it will generally be best to adopt some form of dry closet. Hand-flushed water-closets do not work satisfactorily.

(*d*) Where neither sewers nor water service are available, as is often the case in small villages, some form of dry closet will be necessary.

Figs. 77 and 78 illustrate schools designed on 'pavilion'

lines, providing maximum opportunities for the admission of light and air to the rooms.

SECONDARY SCHOOLS AND BOARDING-HOUSES [1]

The requirements relating to height of rooms, lighting, ventilation, heating, water supply, and drainage are, for all practical purposes, synonymous with those set out for elementary schools. Special requirements are as follows:

1. Day Schools

1. *Class-Rooms*

(*a*) At the rate of at least four for every 100 pupils; not designed for more than 30, or less than 15, pupils; desirable to have one or more division rooms in addition to the regular class-rooms, to take from 10 to 15 pupils each; a lecture room if suitably arranged may be counted as the equivalent of one class-room.

(*b*) Designed to take single desks, with a gangway of not less than 18 in. between the rows and between the desks and the wall on each side; a space of 1 ft. between the last row of desks and the back wall, and a clear space for the teacher extending the full width of the room of not less than 7 ft. 6 in. between the front row of desks and the wall. (Each desk may be reckoned as occupying a space of about 3 ft. by 2 ft.) These dimensions provide a floor-space of 16 to 18 sq. ft. per head, according to the size of the class, but in no case must the floor-space be less than 16 sq. ft. per head.

2. *Laboratories*

(*a*) A floor-space of not less than 30 sq. ft. per pupil.

(*b*) Gas and water laid on to benches and demonstration table, and sinks provided.

3. *Lecture Rooms*

(*a*) A floor-space of not less than 14 sq. ft. per pupil for the first 30 pupils, and 12 sq. ft. for each pupil above that number.

(*b*) Windows must not be placed facing either the teacher or the pupils.

4. *Art Rooms*

(*a*) Not less than 30 sq. ft. of floor-space per pupil; a suitably shaped room would be 25 ft. by 30 ft.

[1] *Building Regulations for Secondary Schools*, 1914. Board of Education.

(*b*) Lighted by a large window to the north, as far as possible in one length, not broken up by wide piers; with the top carried close up to the ceiling. Any other windows should be fitted with light-excluding blinds.

(*c*) Provided with a sink having water laid on.

5. *Housecraft Rooms*

(*a*) 30 sq. ft. of clear floor-space for each pupil.

(*b*) A slop sink 12 in. deep. (See 'Domestic Subjects' 10. on p. 143.)

6. *Handicraft Rooms*

Should provide for the instruction at one time of not less than 15 nor more than 30 pupils. The latter number will require about 900 sq. ft. of floor-space.

7. *Preparatory Classes and Departments*

(*a*) A Kindergarten or Preparatory Class should be taught in a light, airy room or rooms, facing south or south-east, and so arranged as to provide an easy way into the open air. The room should have a fireplace.

(*b*) Lavatory, offices, and cloak-room accommodation, arranged suitably for both girls and boys.

8. *Staff Rooms*

(*a*) The Head Master's or Head Mistress's room should be provided with a lavatory and closet.

(*b*) Advisable to place staff rooms in a position facilitating supervision over the playgrounds, access to lavatories, &c.

(*c*) Adequate cloak-rooms, lavatories, and closets apart from those provided for the pupils.

A staff of 3–4 require 2 basins and 1 closet.
A staff of 6–10 require 3 basins and 2 closets.
A staff of 10–15 require 4 basins and 3 closets.

9. *Dining Halls*

(*a*) Not less than 2 ft. should be allowed for every pupil at the table, and not less than 10 sq. ft. of floor-space.

(*b*) Kitchen and necessary offices, which should include a larder and pantry, adjacent to the Dining Hall, with separate entrance, and so placed that the smell of cooking will not be likely to enter the school.

10. *Gymnasium*

(*a*) Constructed with a flat ceiling 16 ft. from the floor and lighted by a continuous range of windows down each side with the underside of the sills not less than 9 ft. from the floor. The windows to be hung on centres to swing open.

(*b*) Means of warming must be provided.

11. *Baths and Lavatories*

(*a*) Lavatory basins provided on the following scale:

Boys—One for every 20 pupils up to 100 and one for each succeeding 25; 18 in. being allowed to a basin.

Girls—One for every 10 pupils up to 100 and one for each succeeding 20.

b) Provision for foot and spray baths may be made.

(*c*) A lock-up slop sink and water-tap for use by the caretaker are desirable.

12. *Closets*

(*a*) Every closet must be not less in the clear than 2 ft. 3 in. wide, nor more than 3 ft.; fully lighted and ventilated, and have a door at least 3 in. short at the bottom, and 6 in. short at the top. The closets are best divided by partitions carried up 6 ft. only.

(*b*) The walls should as far as possible be treated with some smooth hard surface upon which writing is impossible.

(See also Chapter XI, p. 186.)

2. Boarding-houses

1. *Sleeping-Rooms*

(*a*) Floor-space of not less than 65 sq. ft. and a cubic space of 700 ft. for each occupant.

(*b*) Ventilation must be adequate and it is desirable that a through current of air should be provided by arranging the windows on opposite sides of the room.

(*c*) Cubicles if formed out of a dormitory by partitions not carried up to the ceiling should provide the area required above; each cubicle must have its own window.

(*d*) If the partitions are carried right up, not less than 100 sq. ft. of floor-space will be required.

(*e*) Closet accommodation for night use must be provided within reasonable access of each dormitory.

(*f*) An aspect that allows the sun to enter the rooms freely should be chosen—south or south-east being preferable.

2. *Bathrooms, Lavatories, and Offices*

(*a*) The washing arrangements may consist of either ordinary hand basins in the dormitories, or, in the case of boys' schools, lavatories placed conveniently near.
(*b*) Fixed lavatory basins should not be fitted in sleeping-rooms.
(*c*) There should be baths at the rate of 2 for every 20 boarders, with separate bathroom provision for the staff. A good plan for daily use is to have a room with a floor of asphalt, lead, or other impervious material, with taps and movable baths, or shower baths. It should be noted that two shower baths divided by waterproof curtains or partitions will occupy the space of one slipper bath, and can also be used more expeditiously.
(*d*) A downstair changing room and a separate lavatory for day use in connexion with it should be provided.
(*e*) The number of closets required for day use is one for every seven boarders.

3. *Day Rooms*

Rooms should provide not less than 20 sq. ft. of floor-space for each boarder.

4. *Sick-rooms*

(*a*) Properly isolated; the beds free of the walls; a space of not less than 6 ft. between beds, and, if possible, a window between every two beds, the windows being opposite each other.
(*b*) All internal angles of walls, floors and ceiling rounded.
(*c*) 1,000 cu. ft. of air-space per bed.
(*d*) Water-closets and bathroom, with hospital bath provided, with aerial disconnexion from the sick-room.
(*e*) In boarding schools of more than fifty boarders provision for infectious cases should be made in a separate building as far from the main building as can conveniently be arranged.

Day Open-Air Schools

1. *Essential Requirements*[1]

(*a*) Site sheltered but fairly open; one acre, say, for fifty children; should comprise resting shed. Rooms constructed for twenty-five children.

[1] Annual Reports for 1912 and 1913 of the Chief Medical Officer of the Board of Education. See also *Elementary Schools*.

(*b*) Ample ventilation of rooms; adequate protection against stormy weather; and means of heating in winter. May conform to one of three types, viz.:
   (i) Increased open window space.
   (ii) Removal of one side wall, verandah form.
   (iii) A loggia arrangement.

(*c*) A bathroom with shower or spray baths, and ample lavatory accommodation.

(*d*) Facilities for drying wet garments, &c.

Fig. 79 illustrates a plan of an open-air class-room.

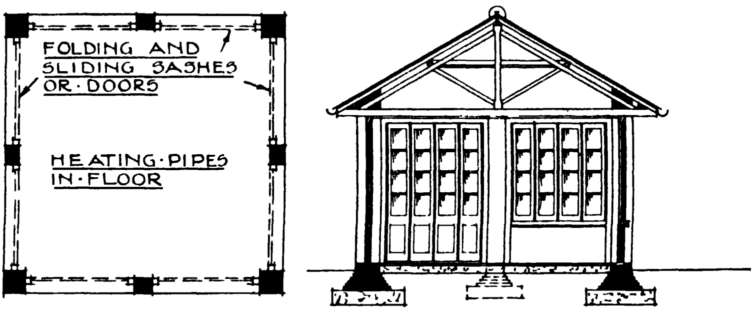


FIG. 79. Plan and section of detached open-air class-room fitted on each side with sashes or, alternatively, doors of full height.

SCHOOLS FOR BLIND, DEAF, DEFECTIVE, AND EPILEPTIC CHILDREN[1]

1. General Rules

(*a*) Rooms for physically defective children should, as a rule, be on the ground floor.

(*b*) All new buildings, whether for day schools or boarding schools, should be planned as far as possible on Open-Air School lines; each room with provision for effective cross-ventilation into the open air, and so constructed as to permit of conversion into an open-air room when desired.

(*c*) Each class-room must contain not less than 15 sq. ft. of floor-space per child. In the case of schools for cripple children, some of whom require couches, at least 18 sq. ft. per child.

[1] *Regulations for Special Schools* (*i.e. Schools for Blind, Deaf, Defective and Epileptic Children*), 1917. Board of Education. These rules must be read in conjunction with the *Building Regulations for Elementary Schools*, p. 138.

(*d*) No class-room should contain less than 200 sq. ft. of floor-space.

(*e*) The light should be ample and such as to suit the mode of teaching employed.

(*f*) Single desks or tables and chairs should be provided.

(*g*) In rooms used for carpentry, metal work, cookery, or laundry work, not less than 30 sq. ft. of floor space; and in rooms used for other forms of manual instruction not less than 20 sq. ft. per child.

2. Day Schools

(*a*) Offices for boys and girls should be separate.

(*b*) Provision should be made for the preparation of meals and for the bathing of the children (preferably by means of spray-baths), unless other arrangements are available for these purposes.

3. Boarding Schools and Homes

1. *Dormitories*

In schools other than sanatorium schools a minimum floor-space of 42 sq. ft., and a cubic capacity of 420 cu. ft. per child. In sanatorium schools 50 sq. ft., and 500 cu. ft., respectively, per child. A separate bed for each child, with sufficient space between the beds. Cross-ventilation where possible; where not obtainable a minimum floor-space of 50 sq. ft. per child.

2. *Dining-rooms and Play-rooms*

(*a*) A minimum floor-space of 8 sq. ft. per child.

(*b*) Except in large schools a room may be provided for joint use as a play-room and dining-room if it contains a floor-space of not less than 20 sq. ft. per child.

3 *Sick-rooms*

Separate sick-rooms for boys and girls consisting of two rooms at least in each case, viz. one for the patients and the other for the nurse. An aspect south-east, south, or south-west is to be preferred. A closet and bathroom in close connexion with the sick-room.

4. *Baths and Lavatories*

Supplied with hot and cold water, and sufficient to enable each child to receive a daily shower or spray bath; some slipper baths to supplement the spray baths; a suitable and sufficient supply

of lavatory basins available for use at all times of the day; water supply sufficient to admit of fresh water for each child; and provision in the bathrooms and lavatories for a separate towel for each child.

5. *Latrines*

(*a*) For day—Closets equal to 10 per cent. on the number of boys, together with a urinal; and 15 per cent. on the number of girls. Facilities for frequent supervision.

(*b*) For night—One or two closets adjoining the dormitories, but disconnected therefrom by a lobby having a current of air by windows on two sides.

SANATORIUM SCHOOLS AND SCHOOLS OF RECOVERY[1]

1. *Type of Building*

(*a*) Not more than two floors; for surgical tuberculosis one-floor buildings.

(*b*) Protection from prevailing winds secured by means of trees, shelters, &c.

(*c*) Day-rooms, dormitories, wards, and class-rooms facing south-east, south, or south-west.

2. *Wards*

(*a*) Of the ordinary sanatorium type or in the form of sheds entirely open on the south side and with suitable windows for through ventilation on the north side. If possible, balconies or verandahs large enough for beds.

(*b*) Probably unnecessary to heat the wards artificially. Open fires or heating apparatus doubtless required for dining or day, dressing, and washing rooms.

3. *Day-room Accommodation*

One-third of the floor-space of the dormitory accommodation.

4. *Baths, Lavatories, &c.*

(*a*) Sufficient fitments for each child to have a daily bath. Slipper, and shower or spray installation.

(*b*) Lavatory basins with 'jet' water supply.

(*c*) Sanitary conveniences as for Special Schools.[2]

[1] Suggestions contained in the *Annual Report for 1911 of the Chief Medical Officer of the Board of Education.*

[2] See p. 153.

IX

SPECIAL HYGIENIC REQUIREMENTS: TRADE PREMISES

Factories and Workshops

NUMEROUS requirements relating to the sanitation of factories and workshops are contained in the factory and public health Acts,[1] the enforcement of the requirements being in the hands of the Home Office or the local sanitary authorities. The requirements include the following:[2]

1. *Floor-space.* No standard is prescribed, but the available space has an important bearing upon the general question of air-space and overcrowding and the prevention of accidents.

2. *Air-space.* Overcrowding is prohibited and at least 250 cu. ft. of air-space must be allowed during ordinary working hours and 400 cu. ft. during overtime. If artificial light other than electric light is employed for illuminating purposes, or if a workshop is occupied by day as a workshop and at night for sleeping purposes, higher figures than those given may be substituted by special order issued by the Secretary of State.[3] In certain industries (electric accumulator manufacture, vitreous enamelling of metals or glass), 500 cu. ft. of air-space is specified and the exclusion of any space above 14 ft. from the floor from the calculation; while for wool-sorting and wool-combing 1,000 cu. ft. are required. In the calculation of air-space, rooms separated by doors (even if usually open) or by high partitions should be counted as separate rooms.

3. *Ventilation.* Sufficient means of ventilation must be

[1] Factory and Workshop Acts, 1891–1907; Public Health Acts, 1875 and 1890; and Public Health (London) Act, 1891.

[2] For certain of these notes the *Memorandum upon the Structural Requirements of the Factory and Workshop Acts*, 1912, has been drawn upon.

[3] By an Order—17 January, 1902—the air-space in a workshop occupied at night as a sleeping apartment is increased to 400 cu. ft. See p. 163 as to bake-houses.

provided and maintained. In some industries (e.g. cotton, flax, hemp, and jute) regulations require that the arrangements shall be such that no worker shall be exposed to any draught at a less temperature then 50° F. Standards of ventilation are prescribed in some instances; thus for cotton-weaving mills the proportion of carbonic acid in the air shall not in daylight in humidified rooms be more than 8 parts per 10,000 in excess of the proportion in the outside air at the time; and in dry rooms 11 parts per 10,000. In flax, hemp, and jute mills the corresponding limit in both dry and humidified rooms is 5 parts per 10,000. With certain processes local exhaust ventilation is needed for the removal of dangerous dust or fumes at the point of origin.

In cotton cloth and other humid factories the atmospheric humidity can be controlled, and where the humidity is artificially produced the water used must be taken from a public supply of drinking water, or other source of pure water, or effectively purified, and all ducts for the introduction of humidified air kept clean.

4. *Temperature.* A reasonable temperature must be secured and maintained and this without interfering with the purity of the air. Warming by means of flueless gas stoves is not admissible, and radiators heated by ordinary gas jets are also open to objection.

For purely sedentary work the temperature should not be below 55° F. On the other hand, where great heat results from manufacturing processes means of cooling should be installed or suitable protection afforded the workers. In power laundries, stoves for heating irons must be sufficiently separated from the ironing rooms and from any ironing table. Gas-irons emitting noxious fumes must not be used; and a fan or other efficient means for regulating the temperature and carrying away steam can be insisted upon.

5. *Sanitary conveniences.* Every factory or workshop must be provided with sufficient and suitable sanitary

accommodation, with separate accommodation for the sexes. The sufficiency and suitability of the accommodation is defined by the Secretary of State for Home Affairs as follows:[1]

(*a*) Not less than 1 water-closet for every 25 females; and 1 for every 25 males (provided that if there be more than 100 males, and sufficient urinal accommodation is also provided, there need only be 1 for every 25 up to the first 100, and 1 for every 40 after). (See also Chapter XI, p. 185.)

6. *Lavatories.* In every factory or workshop where lead, mercury, phosphorus, arsenic, or other poisonous substance is used suitable washing conveniences are needed. The general requirements are that the lavatory shall be under cover and that there shall be either:

(*a*) A trough with a smooth impervious surface, fitted with a waste pipe without plug, and of such length as to allow at least 2 ft. for every five persons employed, and having a constant supply of warm water from taps or jets above the trough at intervals of not more than 2 ft.; or

(*b*) At least one lavatory basin for every five persons, fitted with a waste pipe and plug or placed in a trough having a waste pipe, and having either a constant supply of hot and cold or warm water laid on or (if a constant supply of heated water be not reasonably practicable) a constant supply of cold water laid on and a supply of hot water always at hand when required for use by persons employed.

7. *Baths.* In works where lead smelting or smelting of materials containing lead and the manufacture of red or orange lead or flaked litharge, and also where white lead, electric accumulators, bichromate of sodium or potassium, anilin and certain other benzine derivatives and explosives with use thereof are manufactured, baths (to which hot and cold water should be laid on) are required for the use of the employees.

[1] 'The Sanitary Accommodation Order,' 1903. This order does not apply to London nor to districts where the Public Health Acts Amendment Act, 1890, has been adopted.

8. *Cloak-rooms and meal-rooms.* Properly ventilated and warmed cloak-rooms are needed in a number of dangerous and unhealthy industries for the keeping of the employees' clothing during working hours, together with meal-rooms.

9. *Lighting.* Except in particular industries where efficient lighting is required under special rules no specific requirement is made; but adequate lighting should be provided in every room to prevent eye-strain, minimize accidents, and for its bearing upon health generally.

10. *Generally.* Every factory and workshop must be kept in a cleanly state, free from effluvium arising from any drain, water-closet, earth-closet, privy, urinal, or other nuisance; not overcrowded; and ventilated in such manner as to render harmless, so far as is practicable, all the gases, vapours, dust, or other impurities generated in the course of any process carried on and that may be injurious to health. Floors on which any wet process is carried on should be suitably paved and drained, and walls liable to dampness rendered or lined with an impervious material. In particular industries special requirements are enforceable in relation to floors and drainage.

Collieries

General regulations[1] have been made by the Secretary of State for Home Affairs under the Coal Mines Act, 1911, Sections 76, 77 and 86, with respect to bathing facilities and sanitary conveniences. These embrace:

1. *Bathing Accommodation and Facilities*

(1) The accommodation and facilities for taking baths shall be provided in a building of sufficient dimensions, efficiently lighted and ventilated, kept in good repair, and while the accommodation is in use heated to a temperature of not less than sixty nor more than seventy-five degrees Fahrenheit.

[1] General Regulations dated 29 August, 1913, made by the Secretary of State under Sections 76, 77 and 86 of the Coal Mines Act, 1911 (1 & 2 Geo. V., c. 50) specifying sufficient and suitable accommodation and facilities for taking baths and drying clothes.

(2) The accommodation shall consist of spray or douche baths supplied with water at a temperature as near as may be to 100 degrees Fahrenheit, and each bath shall be contained in a cabinet constructed so as to secure privacy and having suitable arrangements for partially dressing and undressing.

(3) The number of baths shall be in the proportion of one to every six persons in the largest shift employed at the mine.

(4) The building shall be constructed of non-inflammable material, and shall have a floor of cement or similar material so graded and drained as to allow any water to run to and be carried away at the sides of the building.

The building shall also be so constructed as to permit of the interior being easily cleaned and to prevent accumulations of dirt in any part, and for this purpose:

(*a*) All corners and ledges shall be rounded and all inner surfaces of the building up to the part from which the roof springs shall be smooth.

(*b*) A space of not less than 1½ in. shall be left between the walls of each cabinet and the sides of the building, and a space of not less than 10 in. between the walls of the cabinet and the floor of the building.

(*c*) The inside wall of the building shall be constructed, to a height of not less than 7 ft. from the floor, of impervious material which is capable of being readily cleaned.

(*d*) Wood shall not be used for the purpose of any inside fittings except seats and doors leading to the outside.

(*e*) The surface of every seat shall be of hardwood, and shall be made in two or more parts, with spaces between the parts of not less than ¾ in.

(5) No water shall be used for the baths which is liable to cause injury to health or to yield effluvia, and for the purpose of this regulation any water which absorbs from acid solution of permanganate of potash in four hours at sixty degrees Fahrenheit more than 0·5 grain of oxygen per gallon of water shall be deemed to be liable to cause injury to health.

(6) The floor of the building, the cabinets, and the inside wall up to height of not less than 7 ft. shall be thoroughly cleansed once every day, and the whole building shall be thoroughly cleansed at such fixed times as shall be decided by the Committee of Management, but at least once in every ten days. If the accom-

modation is used by more than one shift of persons during the day the cabinets shall be cleansed at such intervals during the day as shall be decided by the Committee.

(7) Every person using the accommodation shall be provided with soap, and at the beginning of each week and at such other times as the person in charge of the baths may think necessary, with a clean towel for his sole use.

(8) Arrangements shall be made for suspending in the roof of the building the clothes of each person using the accommodation, by means of a chain, or a cord so treated as to be impervious to moisture, which shall be so arranged and fitted as to be under the sole control of the person to whom it is allotted, and to keep the clothes of such person when suspended entirely separate from the clothes of any other person, and efficient means shall be provided for drying clothes when so suspended.

2. *Sanitary Conveniences*

(1) A sufficient supply of suitable sanitary conveniences shall be provided: (*a*) On the surface, in or adjacent to the winding engine house, and at other suitable places convenient for the persons employed. Where females are employed on the surface, separate conveniences shall be provided for their use. (*b*) Below ground, at or near the pit bottom, and at suitable positions along the main roads.

(2) Every sanitary convenience below ground shall have a portable receptacle constructed of metal, and provided with a metal cover.

(3) A sufficient supply of disinfectant, or dry coal dust, or other suitable material for covering the faeces shall be constantly provided in a suitable receptacle at every convenience below ground and at conveniences (other than water-closets) on the surface.

(4) (*a*) Every sanitary convenience on the surface shall be under cover and so partitioned off as to secure privacy, and, if for the use of females, shall have a proper door and inside fastening. (*b*) Where females are employed the conveniences for each sex shall be so placed or so screened that the interior shall not be visible, even when the door of any convenience is open, from any place where persons of the other sex have to work or pass, and if the conveniences for one sex adjoin those for the other sex the approaches shall be separate.

(5) Every sanitary convenience shall be kept in a cleanly and sanitary condition, and in good repair, and the receptacles of all conveniences below ground shall be emptied and cleaned not less frequently than once in every seven days and oftener if necessary. The receptacles shall be emptied at the surface unless satisfactory arrangements are made for disposing of the contents in the gob, goaf, or waste, or for their destruction in a furnace.

(See also Chapter XI, p. 186.)

Premises where Food is Prepared or Stored

In addition to maintenance of the premises in a clean state, prohibition against the accumulation of refuse, and the taking of precautions against food contamination, special requirements are applicable.

1. *Generally.* In London[1] the following provisions apply to any room, shop, or other part of a building in which any article, whether solid or liquid, intended or adapted for the food of man is sold or exposed or deposited for the purpose of sale, or of preparation for sale, or with a view to future sale:

(i) No urinal, water-closet, earth-closet, privy, ashpit, or other like sanitary convenience to be within or communicate with such room, &c., except through the open air or through an intervening ventilated space.

(ii) No cistern for supplying water to such room, &c., to be in direct communication with and directly discharge into any such convenience.

(iii) No drain or pipe for carrying off faecal matter to have any inlet or opening in such room, &c.

(iv) Room, &c., not to be used as a sleeping place and, so far as may be reasonably necessary to prevent risk of the infection or contamination of any article of food, no sleeping place to adjoin or communicate therewith except through the open air or an intervening ventilated space.

For extra-metropolitan districts similar powers are incorporated in the Public Health Act, 1925, as follows:

[1] London County Council (General Powers) Act, 1908.

(i) No sanitary convenience within, communicate directly with, or so placed that offensive odours can penetrate to the room.

(ii) As in (ii) above.

(iii) No drain-ventilating opening in room; any inlet or opening to drain to be efficiently trapped.

(iv) Room not to be used for sleeping and no sleeping place to communicate so as to cause unreasonable risk of food contamination.

(v) Room to be adequately ventilated (unless used as a cold store).

2. *Bakehouses.*[1] An underground bakehouse, i.e. any baking room of which the surface of the floor is more than 3 ft. below the surface of the footway of the adjoining street or the ground adjoining or nearest to the room, must not be used unless so used prior to 1902. Existing underground bakehouses must be certified by the sanitary authority as being suitable for use as regards construction, light, ventilation, and in all other respects.

A bakehouse must not contain or communicate directly with a water-closet, earth-closet, privy or ashpit; a cistern supplying water must be separate from any cistern supplying water to a water-closet; a sewage pipe or drain must not have any opening in a bakehouse; and places on the same level with the bakehouse and forming part of the same building must not be used as sleeping places unless effectually separated from the bakehouse by a partition from floor to ceiling and provided with an external glazed window of an area of at least 9 sq. ft., of which $4\frac{1}{2}$ ft. must be made to open. In underground bakehouses[2] 500 cu. ft. of air-space is required per person, and 400 in bakehouses not underground, in respect of the period between 9 p.m. and 6 a.m. where artificial light other than electric light is used.

3. *Meat stores, shops, &c.* Regulations[3] made by the Minister of Health and applicable to London, municipal

[1] Factory and Workshop Act, 1901.

[2] Order of 30 September, 1903—Secretary of State for Home Affairs.

[3] The Public Health (Meat) Regulations, 1924, made under the Public Health (Regulations as to Food) Act, 1907.

boroughs, and urban and rural districts embody the provisions of the Public Health Act, 1925, as set out above; place a duty on the occupier to guard against contamination of meat by flies, filth, &c., and lay down requirements in respect of stalls.

4. *Ice cream stores, &c.* It is an offence in London[1] to permit ice creams or any similar commodity to be manufactured, sold, or stored in any cellar, shed, or room in which there is any inlet or opening to a drain, or which is used as a living or sleeping room.

Dairies and Milk Stores

The Milk and Dairies Order, 1926,[2] provides, *inter alia*, for London and the country generally that:

1. *Generally*

(1) Every building used for keeping milk, other than a cold store, shall be provided with a sufficient number of windows or other openings suitably placed and communicating directly with the external air, so as to secure that the building is sufficiently lighted.

(2) All registered premises shall be provided with a supply of water suitable and sufficient for the requirements of this order.

(3) Milk shall not be deposited or kept:

(*a*) in any room used as a kitchen, scullery, living room, or sleeping room; or

(*b*) in any room or part of a building which communicates directly by door, window, or otherwise with:

(i) any water-closet, earth-closet, privy, cesspool, or receptacle for ashes or other refuse; or

(ii) any room which is used as a sleeping room; or

(*c*) in any room or part of a building in which there is any direct inlet to a drain which is not efficiently trapped.

[1] London County Council (General Powers) Act, 1902.

[2] The Milk and Dairies Order, 1926, made under the Milk and Dairies (Consolidation) Act, 1915.

The requirements (1) and (2) do not apply to any dairy in use as such on 1 October, 1926, until a period of 18 months after a notice has been served by the sanitary authority drawing the attention of the occupier thereto.

2. *Special Provisions Applicable to Buildings used for the Sale, &c., of Milk*

The following provision shall apply to any building or part of a building which is used for the sale of milk or in which milk is kept or used for the purpose of sale or manufacture into butter, cheese, dried milk, or condensed milk for sale:

Except in the case of a building or part of a building which is used for the sale of milk by retail, the floor to be constructed of rendered concrete or other durable and impervious material and to be so sloped as to ensure the removal of all liquid matter which may fall thereon, and to be provided with channels so constructed, sloped, and placed as to receive all such liquid matter and to convey it to a suitable drain or other place of disposal outside the building.

The methods to be adopted to meet the above-mentioned requirements are at the discretion of the sanitary authority. Registration of both the premises and the person carrying on the business is compulsory.

X

SPECIAL HYGIENIC REQUIREMENTS: PUBLIC BUILDINGS, HOSPITALS, AND INSTITUTIONS

Theatres, Music Halls, Dancing Halls, Cinematograph Theatres, and Other Places of Public Entertainment

A LICENCE is needed for places of this character and this fact enables licensing authorities to make such requisitions as may be found necessary irrespective of any regulations relating thereto.

The following requirements[1] are applicable to London, including the City, viz.:

1. *Dressing-rooms, &c.*

(*a*) Dressing-rooms shall not be situated more than one story below the street level.

(*b*) Such dressing-room and staff-room accommodation for performers, musicians, and staff of both sexes as the Council may consider necessary.

(*c*) Performers and members of the orchestra shall not exceed the number for which, in the opinion of the Council, the dressing- and retiring-room accommodation is adequate.

(*d*) Temporary dressing-rooms or quick-change rooms shall not be provided except with the consent of the Council and in accordance with any conditions of such consent.

2. *Natural Lighting*

(*a*) Natural lighting by means of windows or skylights to the auditorium, and (where practicable) to all other parts of such premises. During performances the windows and skylights may be obscured by suitable curtains or shutters.

(*b*) All means for the admission of daylight shall be utilized as far as practicable when the premises are not in use by the public, and windows and skylights kept clean.

[1] *Regulations made by the London County Council under the Metropolis Management and Building Acts Amendment Act*, 1878. (1) The Protection of Theatres, &c., from Fire, 1922; (2) Ventilation of Places of Public Entertainment, 1923; and (3) Rules of Management for Places of Public Entertainment, 1924.

3. *Artificial Illumination*

(*a*) While the public are on the premises the lighting on each of the two systems (e.g. two independent electric, electric and gas, electric and oil or candles, or gas and oil or candles) shall be fully maintained in all parts of the premises, other than the auditorium, to which the public have access. In all parts of the auditorium sufficient illumination to enable the public to leave the premises safely shall be maintained on each of the two systems during the whole time that the public are on the premises.

Provided that so long as there is sufficient daylight in any part of the premises accessible to the public, artificial light need not be maintained in such part.

(*b*) Dressing-rooms and other parts of the premises used by the staff shall be lighted.

(*c*) *Cinematograph theatres*:

(i) The lighting maintained in the auditorium in order to ensure orderly conduct shall be as great as is possible without detriment to the pictures, and in no part of the auditorium less than 0·025 candle-foot, measured at 3 ft. 6 in. above floor level.

(ii) The relative position of the picture-screen and the seating shall be such that undue eye-strain is not caused.[1]

4. *Seating*

(*a*) The seating area assigned to each person shall not be less than 2 ft. 4 in. deep where backs are provided, 2 ft. deep where backs are not provided, 1 ft. 8 in. wide where arms are provided, and 1 ft. 6 in. where arms are not provided. There shall be an unobstructed seatway at least 1 ft. in depth, measured between perpendiculars, between the back of one seat and the front of the seat immediately behind.

[1] The Council will regard this rule as having been complied with if the arrangements are in accordance with the recommendations, as follows, contained in the report dated June, 1920, of the Committee on Eye-strain in Cinemas which was appointed by the Illuminating Engineering Society:

(i) That the angle of elevation, subtended at the eye of any person seated in the front row by the length of the vertical line dropped from the centre of the top edge of the picture to the horizontal plane passing through the observer's eye, shall not exceed 35 degrees, the height of the eye above the floor level being assumed to be 3 ft. 6 in. (ii) That, provided recommendation (i) is complied with, the angle between the vertical plane containing the upper edge of the picture and the vertical plane containing the observer's eye and the remote end of the upper edge of the picture should not be less than 25°.

(*b*) Not more than one child shall be accommodated in any seat constructed to hold one person only. Provided that for the purpose of this rule an infant in arms shall not be regarded as a child.

5. *Ventilation*

(*a*) All parts of such premises shall be efficiently ventilated.

(*b*) Means of ventilation to the auditorium capable of providing a supply of out-door air at the minimum rate of 1,000 cu. ft. per occupant per hour shall be installed.

(*c*) The distribution of the entering air such that all occupied parts of the building, including entrance vestibules, waiting spaces, and refreshment saloons, are reached and the vitiated air effectually displaced.

(*d*) Independent means of extraction from lavatories and sanitary conveniences provided, and so arranged that the air movement shall not be from the lavatories and conveniences into the public parts.

(*e*) The stage shall be ventilated.

(*f*) Permanent ventilation shall be provided to dressing-rooms by means of flues built into the brickwork.

(*g*) Ventilation direct to the outer air shall be provided to the corridors in the dressing-room block.

(*h*) Ventilating shafts from kitchens shall be constructed so as to allow of frequent cleaning.

(*i*) The means of ventilation shall be used continuously while the public are on the premises so as to provide efficient ventilation.

(*j*) At all premises in which lengthy cinematograph displays will be regularly given, a permanent enclosure entered from and ventilated direct to the outer air and having a window or skylight shall be provided.

(*k*) If an organ be installed in any such premises, the supply of air for the organ shall be drawn from the auditorium. The blower-room shall be ventilated direct to the open air.

6. *Sanitary conveniences*

Water-closet and urinal accommodation shall be provided approximately in accordance with the following scale:

(*a*) *Water-closets.* For males: One water-closet for the first 200 or part thereof; two water-closets for 200–500; three water-closets for 500–1,000; and an additional water-closet for every 500 or part thereof over 1,000. For females: One water-closet for the

first 100 or part thereof; two water-closets for 100–250; three water-closets for 250–500; and an additional water-closet for every 400 or part thereof over 500.

Urinals. In each part of theatres and music halls, one urinal stall for each 50 males. In each part of dancing halls, concert halls, restaurants, and cinemas, one urinal stall for each 100 males.

For the purpose of this regulation it shall be assumed that the public in each part of the premises consists of equal numbers of males and females.

(*b*) For the staff and employees, and for the performers and the orchestra, such separate water-closets and urinal accommodation as may be required by the Council.

(*c*) Urinal stalls shall be fitted with automatic flushing apparatus and of a pattern approved by the Council. Water-closets, urinals, and drains shall be constructed in accordance with the by-laws relating thereto.

(*d*) The floors of all water-closet and urinal apartments, and of the lobbies approaching such apartments, shall be constructed of impervious material and sloped to a drain.

(*e*) Water-closet and urinal apartments shall not, except where unavoidable, be approached from the auditorium or from spaces in which the public will await admission.

(*f*) In all premises in which lengthy cinematograph displays will be regularly given, a water-closet shall be provided contiguous to the operating enclosure.

(*g*) An adequate number of water-closets shall be available free of charge if and as required by the Council.

7. *Drainage*

(*a*) The lowest part of the floor of the pit or stalls shall not be lower than the level at which it can be effectually drained by gravitation into a public sewer, and not more than 15 ft. below the level of the street at the principal entrance to the pit.

(*b*) In no case shall the lowest floor be placed at such a level as will render it liable to flooding, and such premises shall be efficiently and properly drained.

8. *Cleanliness, &c.*

(*a*) All parts of the premises and any yard attached thereto shall be kept in a clean and wholesome condition.

(*b*) A sufficient number of metal receptacles with properly fitting covers shall be provided for dust and refuse, maintained in a clean and wholesome condition, and kept in approved positions.

Voluntary Hospitals

The Voluntary Hospitals Commission[1] suggest:

1. *General Disposition of the Buildings*

The wards should be so disposed as to obtain the maximum amount of sunshine, the pavilions being arranged with their axes approximately north and south. The amount of sunshine obtained appreciably affects the cost of heating. Buildings which would interfere with the lighting of the wards should be arranged on the north side.

2. *Bed-space*

(*a*) *In main wards* for adults, a wall-space of 8 linear ft. per bed, a floor-space of not less than 96 sq. ft., and a cubic space of not less than 1,056 ft. In wards specially designed for children, wall-space not less than 7 ft., floor-space 77 sq. ft., and the cubic space 847 ft.

From sixteen to twenty-four beds, arranged in two rows, is the most convenient number for general wards, but, if open-air wards are provided, it is better to have a single row of beds with facilities for removing them to a verandah. At least one small separation ward should be provided in connexion with each large ward. Sanitary annexes with cross-ventilated entrances should be arranged so as to be readily accessible both from the larger and the separation wards. In each large ward a fixed wash-basin for the use of the staff, with hot and cold water laid on, is a convenience, and saves a good deal of unnecessary labour. Sink and sluice rooms are essential.

(*b*) *In open-air wards* having a single row of beds, the wall-space the same as in main wards. For adults the floor-space can be reduced to 88 sq. ft., and the cubic space to 968 ft. For children, the cubic space should not be less than 700 ft.

(*c*) *In separation wards*, for one bed only 120 sq. ft. of floor-space and 1,200 cu. ft. are advisable. For more than one bed, the standards recommended for main wards should apply.

[1] *Memorandum on the Construction of Voluntary Hospitals*, 1926. Ministry of Health.

The height of the large wards not more than 12 ft. nor less than 11 ft., but in the smaller wards a minimum of 10 ft. can be accepted.

The accommodation for children should allow the separation of these patients into small groups so as to diminish the risk of infection, and the importance of provision on open-air lines should be borne in mind.

In most hospitals the provision of some day-room accommodation, in which meals can also be served to patients who are up, would be a convenience.

3. *Operating Section*

The operating section should be arranged in a convenient central position with northerly aspect.

4. *Administrative Accommodation*

(*a*) *Kitchens*. The kitchens and cooking department may be placed on the top of other accommodation so as to secure upward ventilation, but, if not, should be in a one-storied building.

(*b*) *Mortuary*. The mortuary should be a secluded and detached one-storied building so placed as to facilitate the removal of a dead body by a vehicle. Suitable arrangements should be made for conducting post-mortem examinations. Ample means of ventilation are necessary, and proper facilities for enabling relatives and friends to view a body without entering the mortuary itself. If there is a pathological laboratory, it should be planned in close relation to the mortuary.

(*c*) *Laundry*. The planning of the laundry will depend on the size of the hospital. For larger institutions, the following accommodation is desirable, namely: a receiving and sorting-room, a general wash-house, a drying-room, an ironing-room, and a delivery-room. A mess-room and lavatory accommodation for laundry-maids may also be required. If a large laundry is planned, better supervision and ventilation can be maintained if there are no internal dividing walls. It is a convenient arrangement to place the drying apparatus centrally.

5. *Construction*

(*a*) *Floors*. Floors are best constructed of concrete or other fireproof materials; but in small hospitals, floors constructed of timber joists covered with boards and plastered on the underside may be used. Floor coverings with open joints should be

avoided. Fireproof floors may be covered with wood boards in narrow widths or with wood blocks; or, for floors not laid on solid ground, linoleum or cork lino may be laid direct on the concrete when the latter is quite dry. In the case of bathrooms, sanitary annexes, main corridors, &c., impervious floors should be provided.

(*b*) *Interior linings.* The interior linings of all walls, &c., where plastered, should be of hard, non-porous plaster finished smooth. For the interior decoration of the walls of temporary buildings distemper will serve, but for more permanent buildings plain painting is desirable. Tiles, glazed bricks, or other similar linings, if employed, should be reduced on account of the cost to the minimum and confined to corridors, bathrooms, sanitary annexes, kitchens, and similar offices.

All interior angles should be rounded or splayed off. All joinery should be as plain as possible, and projecting or recessed members avoided as far as practicable.

(*c*) *Sanitary fittings* require to be carefully selected with a view to their efficiency, cleanliness, and lasting quality. Unnecessarily expensive or special fittings are deprecated where the ordinary type will serve the purpose, e.g. for hospital slop sinks the ordinary slop-hopper with suitable means of flushing, and with hot and cold water-taps above, is sufficient and considerably less costly than more specialized apparatus.

(*d*) *Heating.* Systems of heating will be dictated by locality and circumstances, but steam-pipes or radiators for warming should be avoided. Low-pressure hot water and open fires may be employed, but at least one open fire is advocated in each ward.

For certain purposes steam is necessary, and an ample supply of hot water should always be provided.

(*e*) *Windows.* The type of window must be carefully selected. Preferably it should be of the double-hung sash order, with hopper above, or entirely on the hopper principle. The windows should extend to as near the ceiling as possible and to within 2 ft. 6 in. or 3 ft. 6 in. of the floor. The amount of glass surface in a ward should be of a proportion of about 1 sq. ft. to about every 80 cu. ft. of air-space.

Verandahs should not be enclosed with glass; as an alternative the provision of sliding windows to the wards deserves consideration.

Isolation Hospitals

A memorandum issued from the Ministry of Health stipulates:[1]

In the ward-blocks (except cubicle-blocks) of hospitals for infectious diseases other than small-pox, each bed must have at least 12 linear ft. of wall-space, 144 sq. ft. of floor-space, and 1,872 cu. ft. of air-space. In the case of small-pox hospitals, however, a minimum air-space of 2,000 cu. ft. per bed is required, and this space must be obtained by increasing the floor-space per bed, since any height of wards above 13 ft. should not be taken into account. The walls of adequate thickness; and the inner face as well as the floors and woodwork should be constructed with smooth impervious surfaces and rounded angles, so as to facilitate cleanliness and to avoid spaces which may harbour dust and dirt. Ventilation by windows on opposite sides of the ward; the windows double-hung sashes with fanlight above, and the fanlight made to fall inwards, hopper-fashion, with side cheeks to prevent down draughts. The area of the windows sufficient but not excessive; 1 sq. ft. of window to every 70 cu. ft. of air-space is a suitable proportion. The best aspect for the ward-blocks is usually with the windows facing respectively south-east and north-west. The wards should have adequate means of warming, which may with advantage be so contrived as to furnish a supply of warm fresh air. An ample supply of hot water for baths provided, and bathrooms capable of being warmed. The closets and slop sinks placed in annexes separated from the wards by cross-ventilated lobbies. The closets should be water-closets where practicable; and the slop sinks of an appropriate pattern adapted to receive the solid and liquid contents of bed-pans, the waste pipe being 3 in. in diameter and arranged similarly to the soil-pipe of a water-closet.

The out-offices will comprise such buildings as laundry, disinfecting-chamber, and mortuary. Except in very small hospitals, the laundry should comprise a wash-house, a drying-closet, and an ironing-room. An apparatus should be provided for the disinfection by steam of bedding and articles which cannot be washed. The mortuary should be in a cool and unobtrusive position, and lighted from the north only.

[1] *On the Provision of Isolation Hospital Accommodation by Local Authorities*, 1924.

A discharging-block is not infrequently provided, consisting of an undressing-room, a bathroom, and a dressing-room, in which convalescents may take their final bath and put on clean clothes before leaving the hospital.

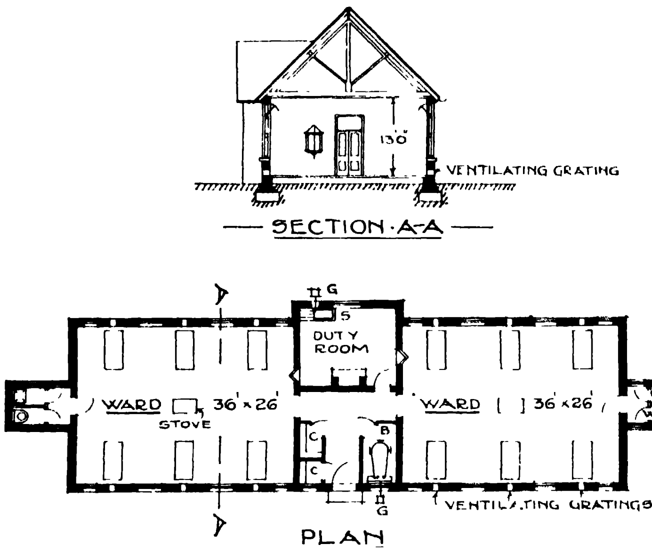


FIG. 80. Typical plan of a small isolation hospital (Ministry of Health model).

Any building intended for infected persons or things should be at least 40 ft. distant from any of the other buildings.

If, owing to the bleakness of the site, it is considered desirable that the several blocks should be connected by covered ways, these should not be enclosed, but should be open at the sides. A screen for protection against wind and driving rain may be provided if desired.

Fig. 80 shows a typical plan of a small hospital.

Poor Law Infirmaries[1]

(*a*) Airing courts should have a good south aspect; and verandahs and balconies a south or south-east aspect.

[1] *Memorandum on the Construction of Poor Law Infirmaries*, 1906. Local Government Board. See also *Workhouse Buildings*, p. 175, the notes on which should be read in conjunction with the above.

(*b*) All internal angles of rooms, &c., should be concave and corners rounded, and all ledges, projections, beads, &c., avoided as far as possible.

(*c*) Baths should be of glazed stoneware or vitreous enamelled iron, placed with their feet towards the external wall (and light), with space on both sides; the fittings of a capacity to enable the

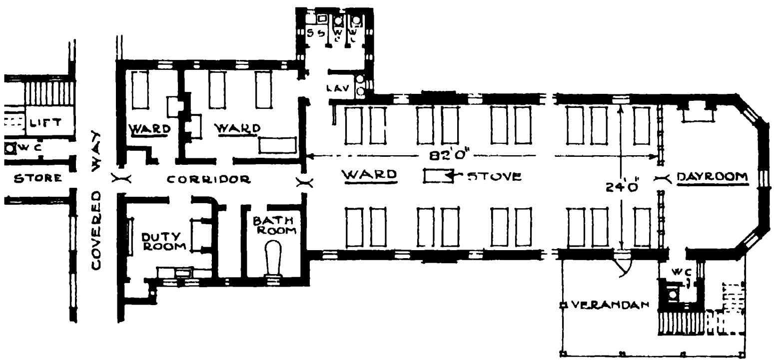


FIG. 81. Typical plan of a Poor Law hospital pavilion block (Ministry of Health model).

baths to be rapidly filled and emptied; and hot-water taps to baths fitted with movable keys.

(*d*) The sink-closets should be fitted with proper hospital sinks suitable for cleaning bed-pans, &c., and with shelves and racks for bed-pans and other utensils.

(*e*) Glazed bricks may be used in the closets, bathrooms, and passages as dados to a height of about 4 ft. 6 in.

(*f*) Floors of passages and sanitary conveniences may be of concrete laid with tiles, or floated to a fine surface, or of terrazzo.

Fig. 81 illustrates a block or pavilion of approved type.

Workhouse Buildings[1]

1. *General Arrangement*

(*a*) Blocks of buildings sufficiently apart to allow free access of light and air, and an aspect securing exposure to sun of space between the blocks.

[1] *Extracts from Memorandum entitled Points to be attended to in the Construction of Workhouse Buildings*, 1891. Local Government Board.

(*b*) Airing-yards to have best practicable aspect, suitably surfaced and drained, with open sheds for sheltering the sick and aged in wet or inclement weather.

(*c*) Sleeping-rooms to be ceiled at the level of the wall-plate.

(*d*) Walls of sick-wards to be plastered internally with a hard or non-absorbent plaster, or painted to a height of 6 ft. from floor.

(*e*) Suitable mortuary to be provided with ample roof ventilation, water-supply, and drainage.

(*f*) Wash-house, laundry, and drying closet to be provided.

(*g*) A detached wash-house for washing infected linen, &c., adequate means for disinfecting linen, clothes, bedding, &c., are needed, and a room for drying vagrants' clothes.

2. *Floor-space, Cubic-space, &c.*

Room.	*Width of room in ft.*	*Height of room in ft.*	*Floor-space in sq. ft.*	*Cubic-space in ft.*
Receiving Wards.				
	—	10	40	—
Main building.				
Dormitories	18	10–12	36	360
Do. (Women with infants) . .	18	10–12	50	500
Do. (occupied by infirm inmates day and night)	18	10–12	50	500
Day-rooms	—	—	15	—
Refractory wards	—	—	60	—
Imbecile Wards.				
Dormitories	—	10	50	500
Day-rooms	—	10	20	200
Sick Wards.				
Wards (general)	20–24	10–12	60	600
Itch and Venereal	12 (one row of beds).	10–12	60	600
Lying-in	20–24	12	80	960
Offensive cases	12 (one row of beds).	12	80	960
Children	18–20	—		—
Day wards	20–24	10–12	20	—
Isolation Wards.				
			144	2,000

Room.	Width of room in ft.	Height of room in ft.	Floor-space in sq. ft.	Cubic-space in ft.
Vagrant Wards.				
Associated wards	18	12	—	—
Wards on cell system . . .	4	10	36	360
Do. (Women and Children) . .	5·5	10	54	540

3. *Lighting and Ventilation*

(*a*) Dormitories, wards, and day-rooms to have adequate means of through ventilation by opposite external windows, and means for warming the incoming air when necessary; windows to extend to within 1 ft. of ceiling, and area to be 1 sq. ft. to every 70–80 cu. ft. of space.

(*b*) Dining-hall to be well lighted, ventilated, and warmed, with means of ventilation for complete and rapid removal of the smell of food.

(*c*) Kitchen and scullery to have ample means of roof ventilation and means for carrying off steam and smell of food. Larders to be cool and ventilated.

(*d*) Workrooms to be light, airy, and as spacious as day-rooms.

(*e*) Refractory wards to be properly lighted and ventilated.

(*f*) Imbecile wards to be treated as sick wards.

(*g*) Vagrants' sleeping-cells to have means of constant through ventilation.

(*h*) Wash-house and laundry to have open roof and louvre ventilators.

4. *Water-supply, Baths, Sanitary conveniences, &c.*

(*a*) Drinking-water cisterns to be easy of access for inspection and periodical cleansing.

(*b*) Baths and lavatory basins to be provided in Vagrant Wards at the rate of one bath and one basin for every seven or eight persons. Receiving wards and vagrants' sleeping-cells and wards to be reached from bathroom without passing through the outer air.

(*c*) Water-closets and slop sinks to be fixed in projections with intervening lobby. Cross-ventilation to be provided to apartment and lobby.

(*d*) Itch and venereal wards to have distinct water-closet and lavatory accommodation, and receiving wards independent water-closets, baths, and lavatories.

(*e*) Refractory wards and vagrants' cells to be furnished with suitable means of obeying calls of nature.[1]

(*f*) Slop and waste-water shoots to be provided on bedroom floors.

Mental Hospitals

The Commissioners in Lunacy have issued *Suggestions and Instructions* with reference to sites and construction of buildings.[2] These include:

1. *Sites*

Land of a healthy character and offering facilities for construction, where necessary, of a system of under drainage; chalky, gravelly, or rocky subsoil most desirable; not near to any nuisances or offensive manufactures; elevated, undulating in its surface, cheerful in its position, having general fall to south or south-east, with some sloping land towards the north to which the sewage can be applied by gravitation.

2. *Position of Buildings*

Main buildings to be on northern portion, southern portion being reserved for patients.

3. *Water-supply*

Constant and ample supply of wholesome water not less than 40 gals. per head per diem; storage to be adequate, a reservoir in the ground being preferable to water-towers; materials for pipes and cisterns to depend upon quality of water as ascertained by analysis.

4. *Arrangement of Buildings*

(*a*) *Aspect.* To afford free access of sun and air with, as far as possible, a southern or south-eastern aspect to principal rooms.

[1] A sealed night-stool, earth commode, or other approved contrivance of the kind is suggested.

[2] *Suggestions and Instructions with reference to Sites, General Arrangement of Buildings, Construction of Buildings, Plans and Particulars, Estimates, of Lunatic Asylums.* 1911. Commissioners in Lunacy.

(*b*) *Verandahs.* Wide enough to receive beds; protected from the weather; windows of ward to open above roof of verandah so as not to interfere with the ventilation of the ward.

(*c*) *Day-rooms.* Not less than 40 sq. ft. of floor-space for ordinary patients, and 50 ft. for noisy and turbulent cases; gallery to be provided with minimum width of 10 ft., and area not exceeding 20 sq. ft. per patient; windows of gallery, if possible, to have a southerly aspect.

(*d*) *Dormitories.* Associated dormitories a floor-space of 50 sq. ft., and single rooms 63 sq. ft. per bed.

(*e*) *Height of story.* Not less than 12 ft. from floor to floor.

(*f*) *Nurses' bedrooms.* An area of 100 sq. ft.

5. *Construction of Buildings*

(*a*) Walls to be damp-proof; if with cavity, inner half at least one brick thick; damp-course to be provided.

(*b*) Floors of sculleries, lavatories, urinals, and water-closets of cement, tiles, or other non-absorbent material; a layer of cement-concrete not less than 4 in. thick under all boarded floors at the ground level.

(*c*) Walls of kitchens, sculleries, larders, and general bathrooms may be faced internally with glazed brickwork or tiles the whole height; other bathrooms, lavatories, water-closets, slop-rooms, staircases, and main corridors to dado height with cement or hard plaster above; other walls plastered or cemented.

(*d*) Windows in habitable rooms one-tenth of floor-space; lowest clear glass-line in day-rooms not more than 2 ft. 6 in. above floor; opening of sashes to be limited to 7 in. at top and 5 in. at bottom.

(*e*) Open fireplaces in all day-rooms, corridors, and dormitories, with additional means of warming upon an approved system where open fires are insufficient.

(*f*) Every part of building to be thoroughly ventilated.

(*g*) Laundry with separate wash-house for officers' and nurses' linen and a separate wash-house for soiled linen. A disinfector to be provided.

(*h*) Isolation hospital with 2,000 cu. ft. of air-space per patient.

(*i*) Mortuary of two rooms with post-mortem room fitted with washing-up sink.

6. *Sanitary Conveniences, &c.*

(*a*) *Reception-, waiting-, and visiting-rooms.* Lavatory and water-closet accommodation.

(*b*) *Recreation hall.* Dressing-rooms with lavatory accommodation.

(*c*) *Nurses' rooms.* Bathrooms and other conveniences.

(*d*) *Sanitary annexe.* For each ward but separated by a cross-ventilated lobby not less than 5 ft. wide; comfortable temperature to be maintained in annexe. Fitments to be provided:

- (i) One lavatory basin to every six patients, with waste-pipes discharging into open channel carried through the wall.
- (ii) Bathroom with one or two baths.
- (iii) Water-closets—1 to every 12 patients; not less than 3.
- (iv) Separate water-closet for nurses.
- (v) Slop-room with sink.
- (vi) A small room for soiled linen.

(*e*) *Ward scullery.* A wash-up sink.

(*f*) *General bath-house with attached dressing-rooms.* Six to twelve baths; fixed divisions between baths not desirable, but provision may be made for curtains; baths of Stourbridge ware or specially thick vitreous enamelled iron; not enclosed with woodwork but fitted with hardwood capping rounded and slightly projecting; fixed with head towards centre of room; height not to exceed 26 in.; taps, supply and waste-pipes of large size admitting of ready change of water; supply and waste to be distinct; taps for hot and cold water carefully distinguished, provided with loose keys, or enclosed in locked cupboards.

(*g*) *Water-closets.* Of wash-down type, with hinged hardwood seats to lift up as urinals on the men's side; in sick, infirm, and epileptic wards to occupy all the space between divisions; flushed by separate cistern of 2½ gals. capacity; pulls enclosed in tubes attached to walls or have concealed wires with flush slots; all cisterns and pipes carefully cased in or protected and partitions between closets constructed and fixed so as to avoid facilities for suicide. Urinals not to be provided except in airing-courts, where water-closets and simple urinals may be provided to a limited extent.

(*h*) Best and most approved system of pipe drainage.

Mortuaries

A sanitary authority in the Metropolis is bound to provide a proper place for the reception of bodies before interment. Outside London a local authority may, and if required by the Minister of Health shall, provide such place.[1]

In the construction and fitting up of the building the Model by-laws[2] state that:

(1) The building should be a substantial structure of brick, stone, or other hard and incombustible material.

(2) Every chamber intended for the reception of corpses should be on the ground or basement floor, and in its construction care taken to ensure convenience, decency, cleanliness, and coolness.

(3) The chamber should be lofty, and the area of its floor sufficient to allow freedom of movement between the shelves, slabs, or tables on which the dead are to be placed.

(4) There should be a ceiling to the chamber, or, if it be open to the roof, a double roof with a space of 8 in. at least between the outer and inner covering, or with the addition of an intervening layer of felt or other non-conducting material.

(5) Floors should be solid, of hard, impervious, and non-absorbent material, with even and smooth surface.

(6) Ceilings should be of good plaster or of other equally suitable material, and the internal surfaces of the walls of hard, impervious, and non-absorbent material, the whole capable of being cleansed and disinfected.

(7) Shelves, slabs, or tables may be conveniently placed around the interior of the chamber. These should be of hard, impervious, and non-absorbent material of adequate strength, and capable of being readily cleansed and disinfected, and with a height not exceeding 3 ft. above the floor.

(8) The chamber should be lighted by vertical windows on the north side, lantern lights, skylights, or roof lights being avoided. If it is necessary to place windows on the east or west sides,

[1] Public Health (London) Act, 1891, the Public Health Act, 1875, and the Infectious Disease (Prevention) Act, 1890.

[2] *Mortuaries*, 1913

external louvre blinds should be provided for the windows, but in no case should windows on the south side be used.

(9) Adequate and suitable means of constant ventilation should be provided near the floor-level and at the highest part of the chamber, with all gratings and openings provided for this purpose protected by gauze or other suitably perforated material for the exclusion of flies, vermin, &c., and so arranged as to be removable for cleansing.

(10) The entrance to the chamber should be direct, without the intervention of any passage.

(11) The number of chambers should be at least two, so that one may be appropriated exclusively for the bodies of persons who have died of infectious disease, and the other for the bodies of persons whose death has been due to other causes. It may be expedient to place these chambers as far apart as may be practicable, so that persons visiting the chamber used for the reception of the bodies of those who have died of non-infectious disease may have no reason to fear infection.

(12) Water should be laid on so as to be drawn from a tap within the chamber.

(13) No drain should be within the chamber, but the floor should fall to a channel leading to a trapped gully on the outside of the building.

(14) A sufficient number of shells of different sizes should be kept.

(15) The shells when not in use should be kept in a shed or other suitable place.

(16) Each shell should be constructed of strong wood, painted externally. The interior of the shell and the inner surface of its cover should be lined with tinned copper.

(17) Each shell, after being used and before being deposited in the shed or other place for storage, should be thoroughly cleansed. When the shell has contained the body of a person who has died of an infectious disease, it should be effectually disinfected after being used, and before being so deposited.

Minute care is required with regard to details. Ceilings should be well surfaced and finished with a hard washable enamel; walls finished with a jointless, non-absorbent material such as terrazzo, or rendered in cement with enamel finish; all internal angles of walls and floors

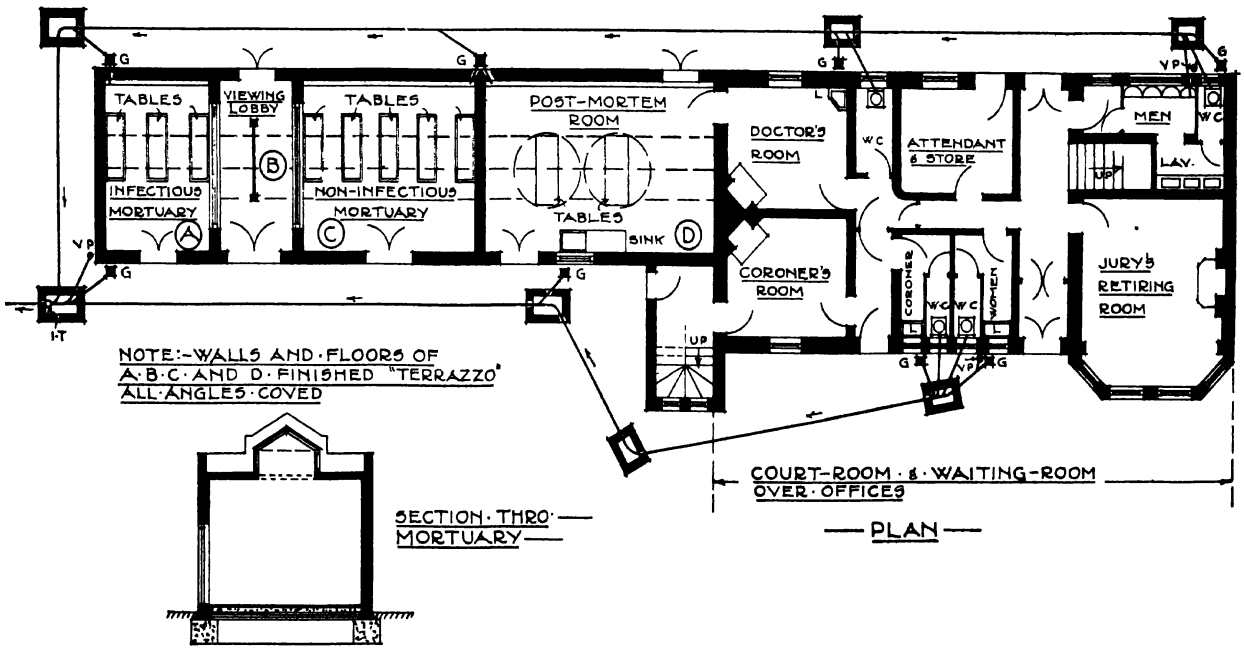


FIG. 82. Mortuary attached to a Coroner's Court. Plan showing lay-out and drainage.

rounded; floors paved with terrazzo or similar material; the minimum amount of woodwork fixed, and all such designed without ledges or quirks; door and other furniture of the plainest description; all woodwork finished with a hard enamel; and complete access for cleaning every part and fitment. Fig. 82 illustrates the general arrangement.

XI

PLANNING AND CONSTRUCTION OF APARTMENTS FOR SOIL, ABLUTIONARY, WASTE-WATER, AND OTHER FITMENTS

THE position, approaches to, and form of construction of apartments containing soil fitments need careful planning if nuisance and the contamination of air and food are to be avoided.

Position and Approaches

Direct entrance from, or aerial communication with, any room used for human habitation, or as a scullery, office, factory, workshop, workplace, or for the manufacture, preparation, storage, or sale of food or drink for man, or from a public room[1] is undesirable. Earth-closets should be entered only from the external air, and privies, owing to inherent probabilities of effluvium nuisance, situated 20 ft. at the least from any occupied building or building used for the storage, &c., of food, and in a position providing ready access for cleansing and for removing filth therefrom without the carriage of the latter through any building. Many codes of by-laws[2] include, either wholly or in part, requirements to this effect, and such requirements are enforceable in all buildings—whatever the use—other than those specially exempt by Act of Parliament.

The Sanitary Accommodation Order, 1903,[3] provides that in factories and workshops a sanitary convenience

[1] That is to say: A room used as or forming part of a church, chapel, or other place of public worship, a hospital, workhouse, college, school, theatre, music-hall, or other place of public entertainment, a public lecture room, public exhibition room, place of public assembly, or a place used for any other public purpose. Vide *By-laws made by the London County Council under section* 39 (1) *of the Public Health* (*London*) *Act*, 1891, *with respect to water-closets, &c.*, and amendments now under consideration.

[2] The Public Health Acts, 1875 and 1890, and the Public Health (London) Act 1891.

[3] Issued by the Secretary of State for the Home Department.

must be accessible; sufficiently lighted and ventilated; have proper privacy—including screening of the interior where persons of the other sex have to pass and, for females, proper doors not less than 6 ft. 6 in. high and fastenings; separate approaches to the respective conveniences for males and females; be under cover, and not in communication with any workroom except through the open air or an intervening ventilated space; with the proviso that with workrooms in use prior to 1903, an approach lobby need not be provided if the workroom is mechanically ventilated in a manner whereby air cannot be drawn into the room through the convenience. Certain of these requirements are applicable to collieries (see Chapter IX, pp. 161 and 162).

Regulations relating to elementary schools[1] specify that water-closets within the main building are not desirable except for teachers; that the conveniences for children should be completely disconnected from the school building, with separate approaches for older boys and girls; in such a position that the convenience cannot be seen into from any window, and so as not to make it necessary to pass the teacher's house in order to reach them; and provided with screened entrances.

In secondary schools similar regulations provide for:[2] girls' offices within the main building, but suitably isolated, or away from the building and connected by a covered corridor; boys' offices completely disconnected from the school buildings; privacy; and offices and approaches for boys and girls wholly separate. At special schools for blind, deaf, defective, and epileptic children the regulations[3] require sanitary conveniences to be distinct from the building, except the closets for night use, which should adjoin the dormitories but be disconnected therefrom by a cross-ventilated lobby.

[1] *Building Regulations for Public Elementary Schools*, 1914. Board of Education.
[2] *Building Regulations for Secondary Schools*, 1914. Board of Education.
[3] *Regulations for Special Schools*, 1917. Board of Education

The practice in hospitals and most institutions is to provide for the location of sanitary fitments in a separate block or annexe approached through a cross-ventilated lobby or corridor. This is officially laid down in respect of mental hospitals, workhouse buildings, poor-law and

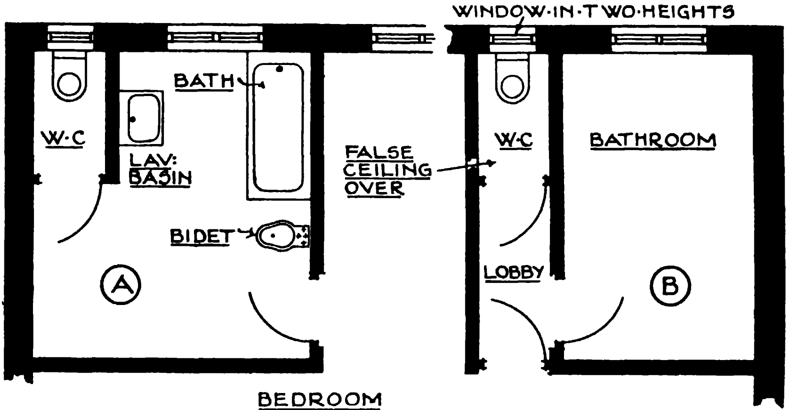


FIG. 83. A. Bathroom approached direct from bedroom with water-closet in separate apartment. B. Water-closet aerially separated from bedroom by ventilated lobby.

isolation hospitals. For police stations, water-closets for the police are usually provided in the yard; but the conveniences for prisoners may be either in the cells or in an adjoining corridor—preferably the latter. In prisons the accommodation is mostly provided in a sanitary annexe or in a corridor adjacent to the cells, although in particular cases the cells are thus fitted.

Aerial Disconnexion

Opinions differ as to whether, under defined conditions, aerial disconnexion of sanitary conveniences is desirable or necessary in the case of bedrooms, as evidenced by the modern practice in hotels of installing water-closets in bathrooms immediately approached from such rooms. In determining the wisdom of this practice regard must be had to the circumstances, for what may be unobjectionable

in a hotel or other building where the fitting-up of the apartment is of the highest standard, and sufficient labour and oversight are available for the maintenance of the fitments and surroundings in a state to which no exception can be taken on sanitary grounds, might conceivably result in definite nuisance in dwellings where a much lower standard of fitting-up and maintenance is found.

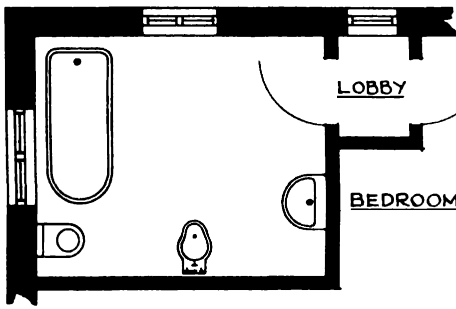


FIG. 84. Combined bathroom and water-closet with intervening ventilated lobby between bathroom and bedroom.

The adoption of such practice does not disprove the general necessity for aerial disconnexion, and where water-closets are required in such a position a separate apartment for the fitment or an intervening lobby should be formed as in Figs. 83 and 84.

The simplest and most effective method of atmospheric disconnexion is an open-air approach. Failing this an intervening lobby is requisite. In premises where the needed accommodation embraces, on the one hand, soil fitments, and, on the other hand, ablutionary fitments in the form of lavatory basins, and the floor-space is limited, the intervening approach lobby may be utilized for the basins. Such use should not, however, extend to baths owing to the likelihood of air-conveyance of vapour into occupied rooms. In hospitals as complete disconnexion as is practicable should be arranged for.

Construction

(1) *Apartments for water-closet, waste-water closet, slop*

sink, and urinal fitments. Apartments of this description and lobbies giving access thereto, within or partly within a building, should have at least one external wall or a roof abutting upon an open space sufficient in area (e.g. not less than 100 sq. ft. and a minimum width of 3 ft.) to provide for lighting and ventilating the apartment; the wall or walls should be of brick, concrete, or other similar and suitable material; be properly ceiled; and have a floor of hard, smooth-surfaced, impervious material—such as cement, asphalt, tiles, mosaic, or terrazzo—laid to approved levels; together with a proper entrance door with fastenings. Every wall of a convenience abutting upon a room used for any of the purposes set out on p. 185 should be rendered with cement mortar.

Walls or partitions between approach lobbies and sanitary conveniences should be made good to ceiling, walls, and floor, and any door provided therein made so as to be close-fitting and self-closing.

Partitions separating soil fitments should be impervious to moisture and stand 3 to 6 in. off the floor, be limited to a height of about 7 ft., and leave a space of not less than 6 in. between the top of the partition and the ceiling, so as to aid cleanliness and ventilation, as in Fig. 91. Marble, enamelled slate, glass, iron—galvanized, porcelain or vitreous enamelled, glazed bricks, and smooth rendered or tiled brick-work or concrete slabs are amongst the utilizable materials. The height and mode of fixing access doors should correspond with the partitions.

The maximum cleanliness is attained if the walls to a height of at least 6 ft. from the floor are rendered in cement trowelled smooth or lined with tiles, mosaic, or similar substance, the internal angles of walls and floor rounded or coved, and the woodwork plain surfaced and painted or otherwise treated so as to be non-absorbent.

Where the sanitary convenience is not within or partly within a building, it should be constructed of brick or concrete with a properly constructed roof and means of

conveying rain-water therefrom, an impervious floor having a fall to the door, and fitted with a suitable door and fastenings.

(2) *Earth-closets and privies.* The following requirements may be accepted as necessary for such conveniences when constructed in urban districts:

An *earth-closet* should

(*a*) Have two external walls abutting on an open space of not less than 100 superficial ft. in extent and 3 ft. in width or depth.

(*b*) Be entered from the external air.

(*c*) If situated wholly or partly within a building be properly ceiled and enclosed by solid walls of brick, concrete, or other suitable material; any such wall, where abutting on any room used for any of the purposes mentioned on p. 185, being finished with an impervious surface.

(*d*) If not wholly or partly within a building be of similar construction to the foregoing, and covered with a properly constructed roof having means for conveying rain-water therefrom.

(*e*) Be paved 3 in. above the adjoining ground surface with a hard, smooth-surfaced, impervious material 4 in. thick laid with a suitable fall to the door.

(*f*) Have the walls of the underseat space rendered with a hard, smooth-surfaced, impervious material, and all wood-work abutting thereon creosoted.

(*g*) Have no connexion with any drain, and be so constructed that. contents of the receptacles for the filth and deodorizing substance are not exposed to rainfall or drainage of waste water or liquid refuse.

(*h*) Be fitted with access doors furnished with fastenings.

A *privy* should

(*a*) Be situated 20 ft. at the least from any building used for the purposes mentioned on p. 185; 100 ft. at the least from a well, spring, or stream of water used or likely to be used by man for drinking or domestic purposes, and in such a position as will not render any such water liable to pollution; and so as to afford ready means of access for cleansing, and for removing the filth therefrom without being carried through any building.

(*b*) Be constructed of brick, concrete, or other suitable material and

covered with a properly constructed roof provided with suitable means for conveying rain-water therefrom.

(*c*) Be paved with a hard, smooth-surfaced, jointless, impervious material, at least 4 in. in thickness with suitable falls to the doors, with the portion in front of the seat 6 in. and the portion under the seat 3 in. above the level of the adjoining ground.

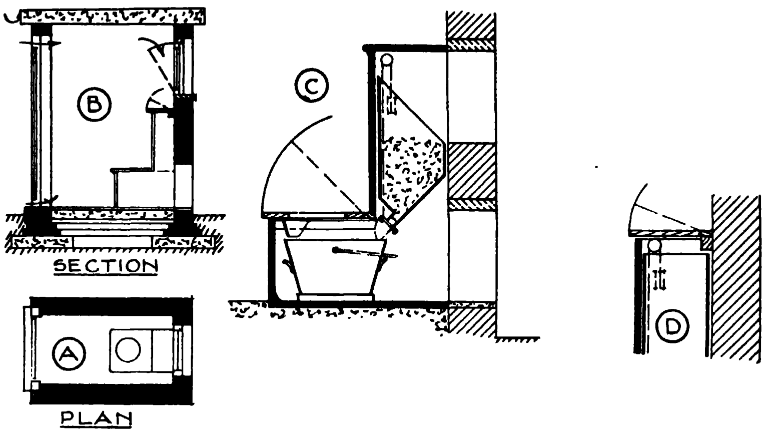


FIG. 85. Earth closet. A and B. Plan and section of apartment. C. Section showing salt-glazed fireclay casing, and galvanized-iron pail and earth container with access from outside apartment. D. Alternative access inside apartment to earth container.

(*d*) Have the walls of the underseat space at least 6 in. thick rendered with a hard, smooth-surfaced, impervious material; a riser of flagging, slate, rendered brickwork, or other hard, smooth-surfaced, jointless, impervious material; all woodwork creosoted; and an access door in the back or side, or, where such door is impracticable, the seat arranged so as to provide access.

(*e*) Have no connexion with any drain, and be so constructed that the contents of the receptacle for filth are not exposed to rainfall or drainage of waste water or liquid refuse.

(*f*) Be fitted with a suitable entrance door furnished with fastenings.

Fig. 85 illustrates an earth-closet and Fig. 86 part of a privy, constructed in accordance with these details and those set out on p. 327, Chapter XVIII. So constructed

the conveniences would comply with the requirements enforceable in most sanitary districts.

Size of apartments. The minimum size of a water-closet, earth-closet, or privy apartment for adult use may be put at 4 ft. 6 in. × 2 ft. 9 in. A more comfortable size is 5 ft. × 3 ft. For children's use 4 ft. × 2 ft. 6 in. may be regarded as sufficient. In elementary and secondary schools[1] the respective maximum and minimum widths allowed are 3 ft. and 2 ft. 3 in.

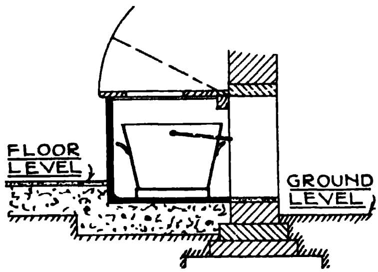


FIG. 86. Privy with salt-glazed fireclay casing and galvanized-iron pail. Floor as shown, but apartment otherwise constructed as in Fig. 85 (A) and (B).

(3) *Apartments for waste-water fitments.* Apartments to receive baths or lavatory basins, sculleries, wash-houses, and laundries, need solid walls and floors, the former rendered or lined and the latter floated or laid with an impervious material of the kind above mentioned, with internal wall and floor angles rounded, and all woodwork designed with the minimum opportunities for accumulating dirt and so treated as to be non-absorbent. Floors should be laid with a fall of about 1 in. in 10 ft. to a drain inlet outside the walls where practicable, in the case of a ground floor, and to a waste-pipe inlet in the case of an upper floor.

In hotels, hospitals, institutions, and other premises having an extensive installation, such construction ought to be obligatory, and it should, wherever possible, be applied to sculleries, bathrooms, &c., in private dwelling-houses. If not applicable in its entirety, the floor under the fitments and the wall-surround should be so formed or finished.

Lighting and Ventilation

In some quarters the value of sunlight as a means of

[1] See footnotes 1 and 2 on p. 186.

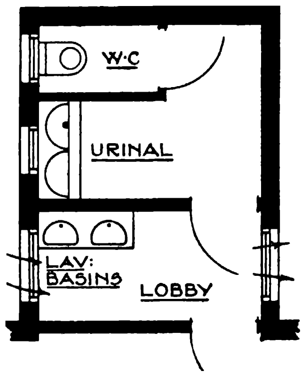
maintaining in a sanitary state apartments containing soil fitments is considered negligible, and it is suggested that all that is needed is frequent air-change. This attitude finds its practical expression in the willingness of some sanitary authorities to permit the construction of apartments without means of external lighting so long as an approved system of mechanical ventilation is installed. New York is a typical example, as the construction of water-closet apartments, bathrooms, &c., without windows is permitted, provided the apartment is ventilated 'by some approved system of mechanical exhaust ventilation of sufficient capacity to provide not less than four changes of air per hour'.[1]

In these days of close attention to hygienic problems, including the development of sun-ray treatment for divers complaints and diseases, it seems a somewhat doubtful proposition to eliminate from enclosed spaces the proved beneficial effect of sunlight on atmospheric conditions, and it is questionable whether such elimination should receive generally the support of hygienists. Altogether apart, however, from the direct benefits of sunlight, experience indicates in an unmistakable manner that apartments used for this special purpose and unserved by natural light are apt to be neglected and dirty, and this notwithstanding the provision of means of artificial lighting. It is therefore suggested that sanitary conditions are best secured by ample direct sunlight (not the mere provision of window-space) coupled with adequate air-change.

For water-closet apartments containing a single fitment many by-laws stipulate a window of a minimum area of 2 sq. ft., the whole of which must open for ventilation, together with an air-brick. For apartments having more

[1] *Code of Building Regulations*, City of New York. It may further be noted that by-laws are now under consideration for London (excepting the City) permitting the construction of water-closet and urinal apartments without an external wall and abutting open space if means of artificial lighting and a system of mechanical ventilation are provided.

than one water-closet, urinal, or other soil fitment the lighting area, whether in the form of windows or other openings in an external wall, or skylights or lantern lights, may be put at one-fifth of the floor-space, exclusive of the frames, with openings for ventilation of not less than one-



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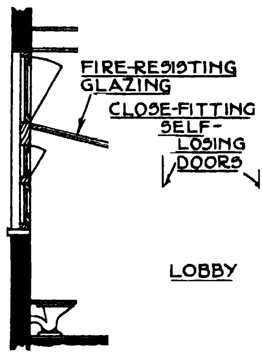

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FIG. 87. Water-closet and urinal apartments with cross-ventilated approach lobby fitted with lavatory basins.

FIG. 88. Intervening lobby lighted and ventilated over ceiling of water-closet.

tenth of the floor-space, and in addition a sufficient number of well-placed air-bricks, air-shafts, or other openings. It is important that the windows or openings shall be so situated as to derive light from the sky, for it is useless to place a window—for lighting—in, say, an external wall which is so overshadowed as to cut off the natural illuminant; and that windows and other openings shall be so placed as to obtain cross- or through-ventilation.

For apartments below the ground level and lacking both an external wall abutting upon an open space and means of roof lighting—such as a basement partly under a public foot-path—fixed pavement or other lights can be utilized of an area equal to one-fifth of the floor-space, and ventilation secured by a suitable method of mechanical exhaust giving not less than ten apartmental changes per hour.

For the ventilation of approach lobbies, openings in

opposite external walls are desirable, as in Fig. 87, but where such cross-ventilation is impracticable at least one window or other opening in the wall of lobby should be arranged for (Fig. 84). If the lobby is unprovided with an external wall, a false ceiling in the form of fire-resisting glazing can be fixed over the soil fitment apartment as in Fig. 88, so as to obtain ventilation for the lobby direct to the external air.

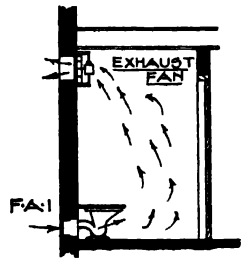


FIG. 89. Sanitary convenience approached direct from work-room and ventilated by exhaust fan.

For conveniences in existing buildings where it is impracticable to construct a lobby, means of mechanical ventilation may be furnished, so designed as to prevent air passing from the convenience into the building from which it is approached. In factories and workshops in use prior to 1903, ventilation by mechanical means so arranged as to prevent air being drawn from the convenience into the workroom is allowed[1] instead of a lobby. Fig. 89 illustrates such a case.

Earth-closets and privies should be sufficiently lighted by a window or opening equal to that suggested for water-closets, with permanent louvred or other openings for ventilation. Doors should be hung so as to leave a space of at least 3 in. top and bottom.

The lighting or window area of bathrooms, sculleries, wash-houses, and laundries may correspond to the foregoing. For bathrooms and sculleries in dwellings the ventilation afforded by the windows is generally sufficient, but in institutions, &c., unless adequate means of cross-ventilation are available, a system of mechanical ventilation is desirable for bathrooms, sculleries, wash-houses, and laundries.

Attention should also be given to the warming of bathrooms in private dwellings, hotels, schools, and institu-

[1] Sanitary Accommodation Order, 1903.

tions. (See Chapter IX, p. 159, for requirements relating to colliery baths.)

Means of artificial lighting are indispensable in all apartments.

Planning

Fig. 71 illustrates a bathroom-scullery for dwellings erected under the Housing Acts; Fig. 83 a private bath-

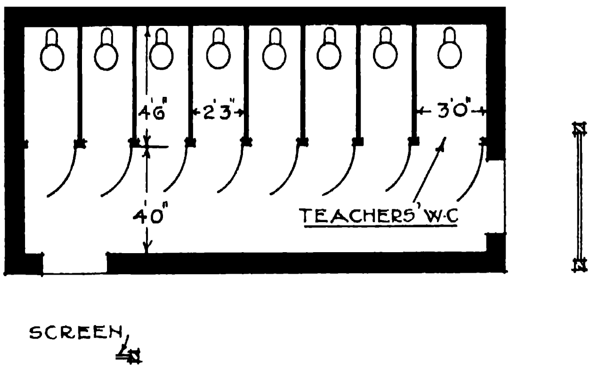


FIG. 90. Plan showing grouping of water-closets for an elementary school.

room in a hotel; Figs. 90 and 91 a group of water-closets; Figs. 92, 93, and 94 a urinal, and Fig. 95 a bath installation for an elementary school; Fig. 96 a school medical inspection and treatment centre or clinic; Fig. 97 a maternity home; Fig. 98 pithead baths to comply with the Mines Act—an arrangement also acceptable for factories; Fig. 81 part plan of one floor of a poor-law hospital—also adaptable for general hospital purposes; Fig. 80 plan of a small isolation hospital; Fig. 99 baths and sanitary conveniences for a man's hostel or common lodging-house; Fig. 100 the lay-out of a mechanical equipment for a steam laundry at a hospital or other institution; and Fig. 101 a small police-station with alternative arrangements for sanitary conveniences.

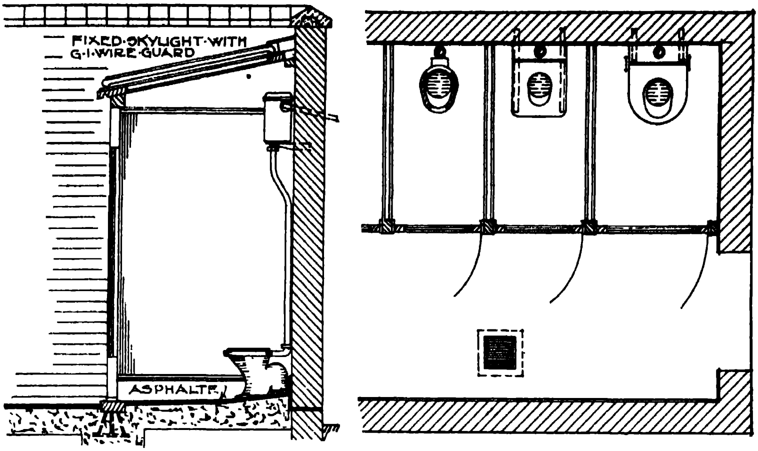


FIG. 91. Enlarged part plan of Fig. 90, and section showing details of construction of water-closets.

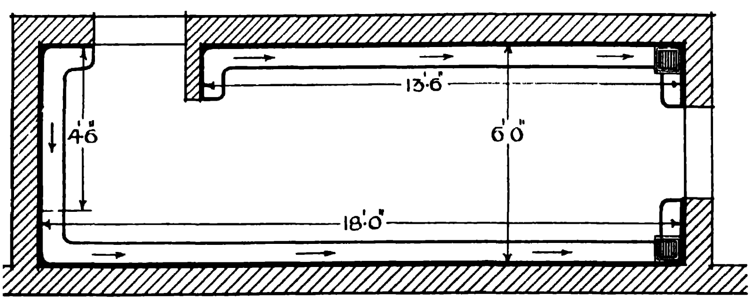
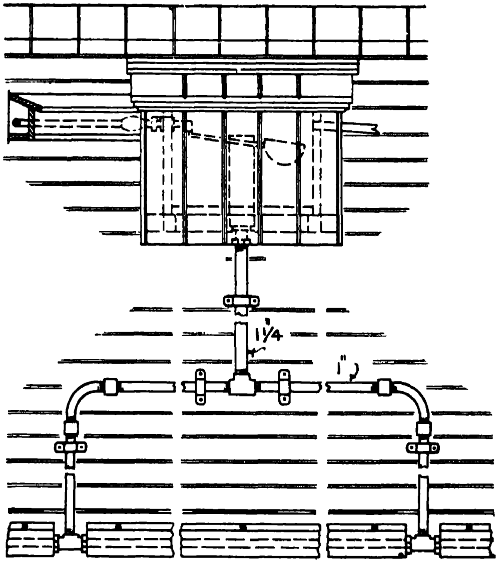


FIG. 92. Plan of 'London-type' urinal for elementary school of 350 boys Walls and floor rendered with mastic asphalt.



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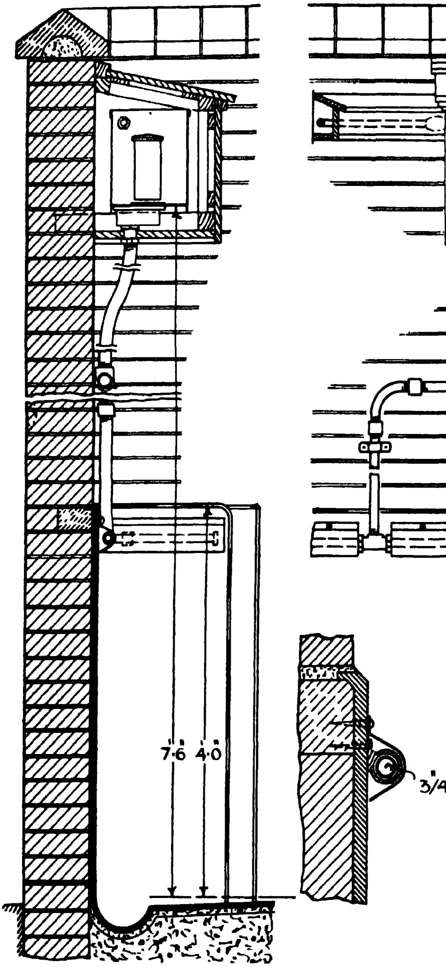

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FIG. 93. Sectional elevation and details of sparge pipe and shield.

FIG. 94. Front elevation showing arrangement of flushing cistern and pipes.

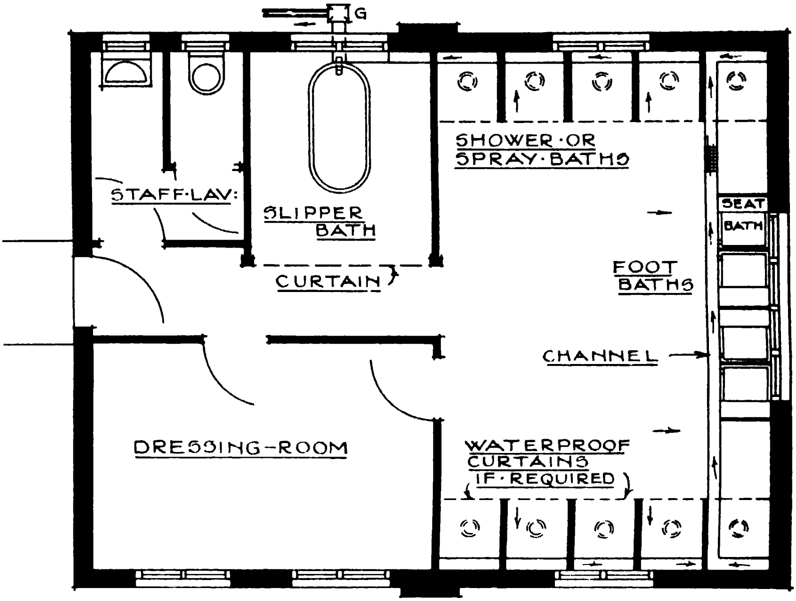


FIG. 95. Bathing installation for an elementary school.

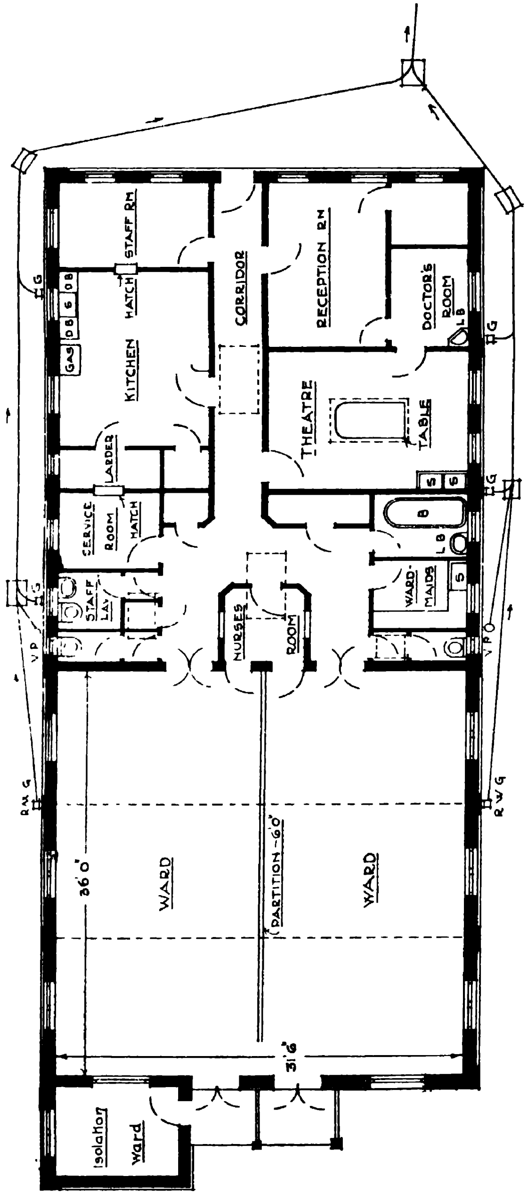


FIG. 96. Plan of school Medical Inspection and Treatment Centre or Clinic.

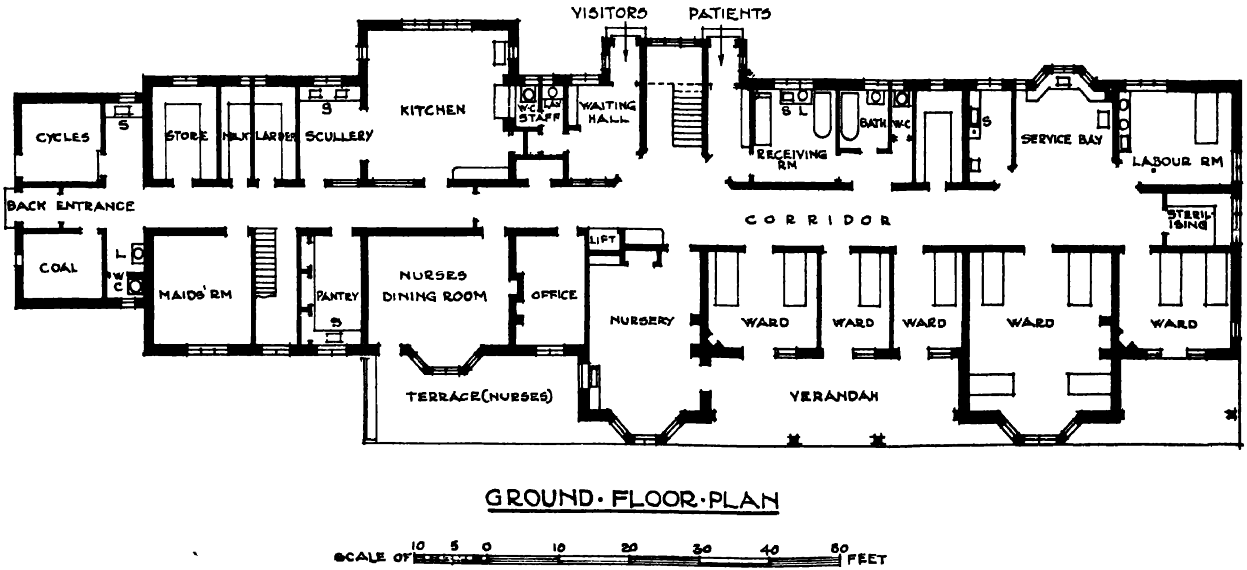


FIG. 97. Plan of one floor of a maternity home (Ministry of Health model).

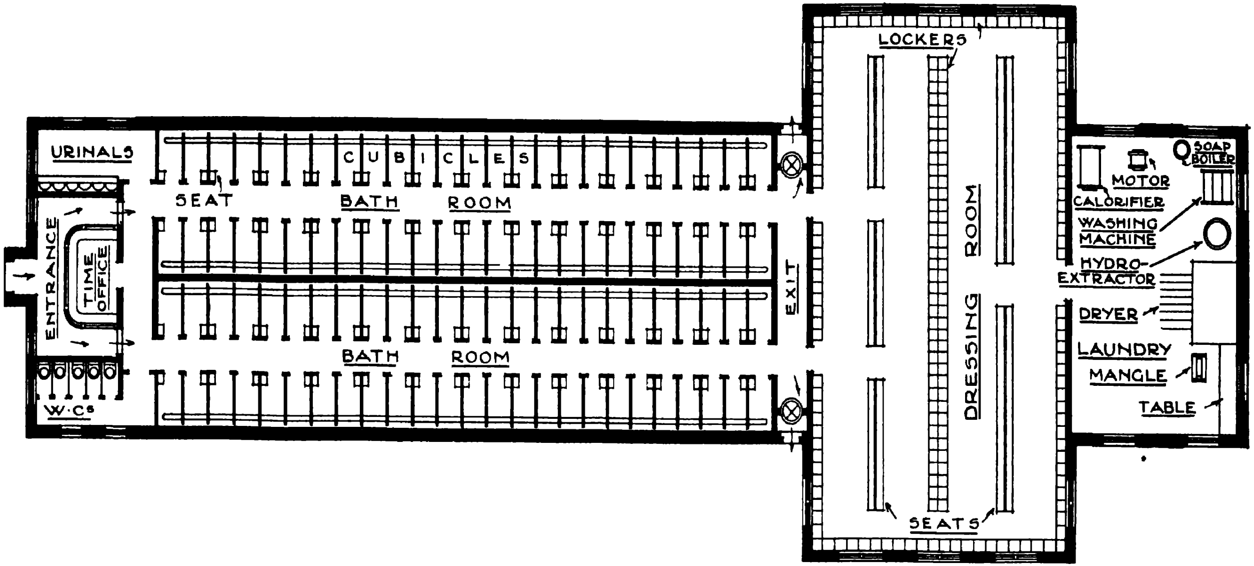


FIG. 98. Plan of pit-head baths to comply with the Coal Mines Act, 1911 (Leeds Fireclay Co., Ltd.).

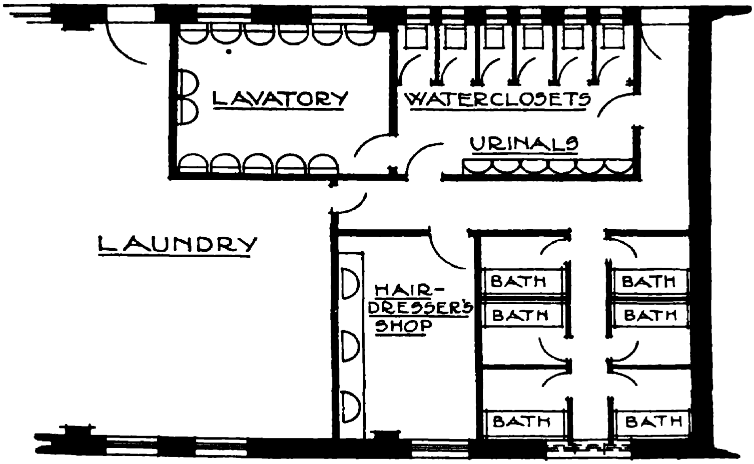
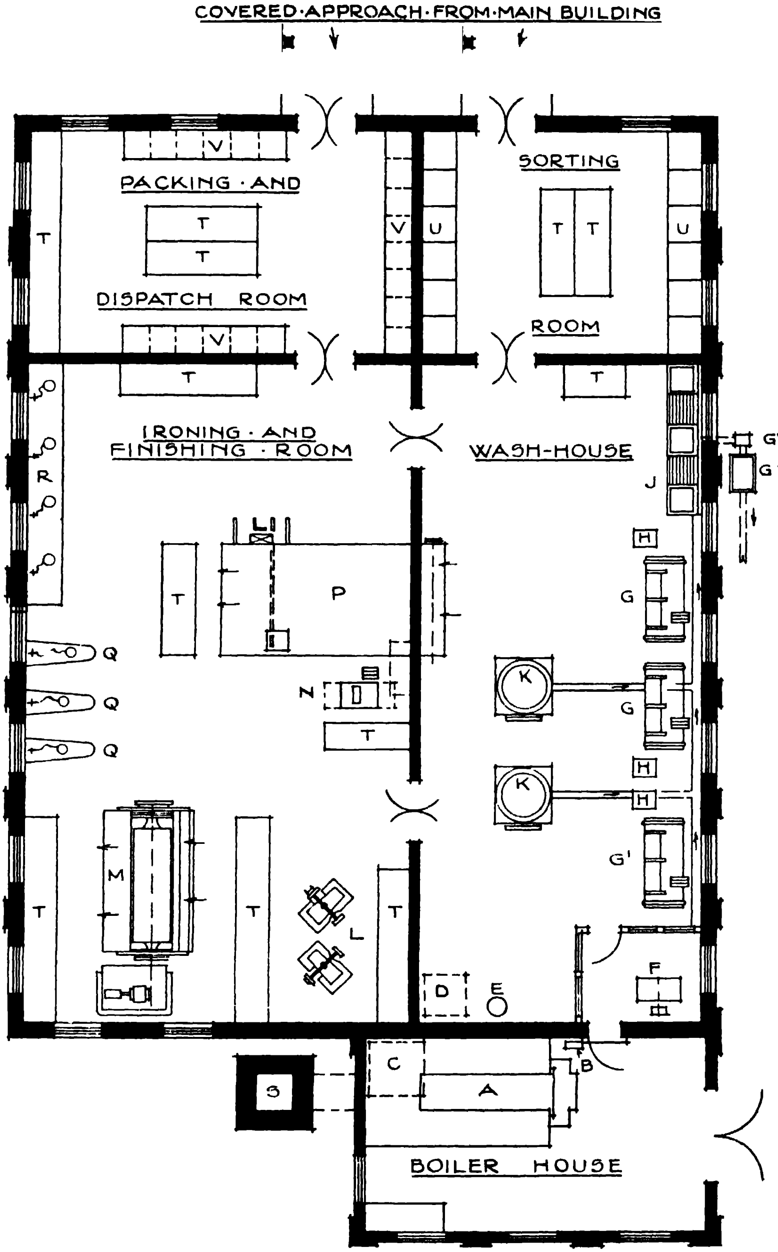


FIG. 99. Baths and sanitary conveniences for a man's hostel or common lodging-house.


COVERED·APPROACH·FROM·MAIN BUILDING
PACKING · AND
DISPATCH ROOM
SORTING
ROOM
IRONING · AND
FINISHING · ROOM
WASH-HOUSE
BOILER HOUSE
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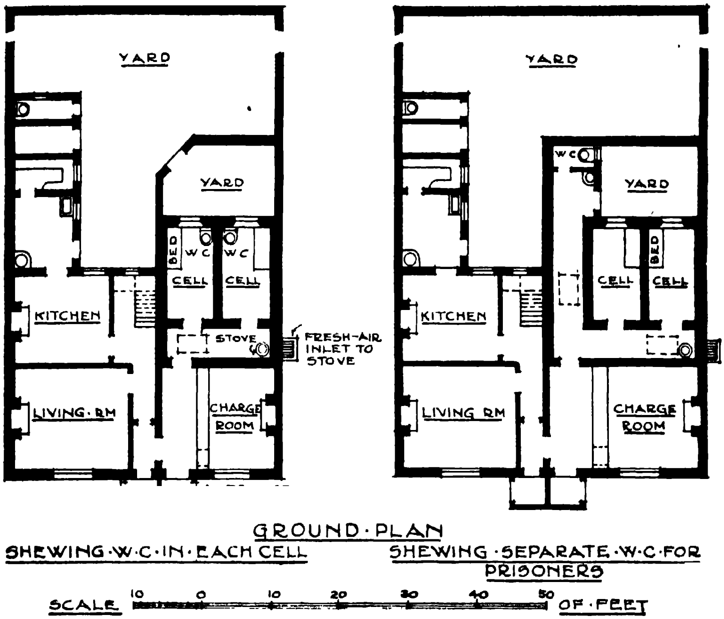


FIG. 101 (*above*). Plan of small police station showing alternative arrangement of sanitary conveniences (Home Office model).

FIG. 100 (*opposite*). Lay-out of a mechanical equipment for a steam laundry at a hospital or other institution (Manlove, Alliott & Co., Ltd.).

A. Cornish boiler.
B. Feed pump.
C. Cold water supply tank.
D. Hot water storage tank.
E. Calorifier for hot water.
F. Electric motor main drive.
G. Washing machine.
G 1. Foul linen washing machine.
H. Soap and soda dissolvers.
J. Wash troughs with scrubbing boards.
K. Hydro-extractors.
L. Garment presses in tandem.
M. Decoudun ironing machine (motor driven).
N. Cuff and collar ironing machine.
P. Continuous drying machine.
Q. Skirt boards with electric irons.
R. Table with electric irons.
S. Chimney shaft.
T. Wood tables.
U. Clothes sorting bins.
V. Clothes storage racks.

XII

THE TRAPPING AND VENTILATION OF DRAIN, SOIL, AND WASTE PIPES

HYGIENISTS differ on the question whether the air-content of sewers, drains, and other pipes or channels conveying decomposable matter of animal origin is dangerous to health. There is, however, ample proof that sewer and drain air is often very offensive, and that such air contains micro-organisms of sewage origin which can be wafted by air-currents through openings in the sewers and drains to the outer air, from sewer to drain, drain to sewer, and even from one drain to another with the connecting sewer as the channel of conveyance. It is conceivable that some of these organisms may be of an infective character, and it is doubtless true that with some persons exposure to drain or sewer air is liable to induce attacks of sore throat and other septic affections, or bring about a physical susceptibility to the onset of disease.

The characteristic of sewer air which is of practical importance is its smell,[1] and of this incontrovertible evidence is found in nuisance from defective drainage and sewerage systems and badly placed ventilating openings. The offensiveness is principally due to gases evolved during the decomposition of sewage retained as a film on the interior surface of the pipe or channel, or as stagnant sewage in badly formed or laid systems. Storage sewers and flat sewers in which sewage is retained are especially favourable to decomposition.

The presence in the air of sewers and drains of bacteria of sewage origin is largely owing to the splashing and agitation of sewage which take place at abrupt falls in the pipes and channels. The most notable of the active chemical changes occurring in the sewage is the evolution

[1] *Report of the Departmental Committee on Intercepting Traps in House Drains*, 1912, p. 46.

of sulphuretted hydrogen, which is offensive, produces distinctive and unpleasant effects on the human system in such small quantities as 0·05 per cent. of the volume of air, and will bring about fatal results in a concentration of 0·1–0·2 per cent. Dr. Haldane found sufficient of this gas given off from house drainage traps (such as large grease traps), in which sewage was retained, to cause symptoms of poisoning in animals exposed to it; while an investigation conducted by him into a fatality at East Ham, where five men were suddenly overcome and drowned in an outfall sewer, showed that the disaster 'was caused by sulphuretted hydrogen, but the conditions which gave rise to the accumulation of this dangerous gas could not be exactly determined, although it was surmised to have been due to the combined effects of a high temperature and a shortage of public water supply, which led to unusually rapid putrefaction of sewage, both in the sewers and in the intercepting traps of house drains'.[1]

In commercial districts where trade effluents are discharged into the sewers much offence may arise from the composition of the sewage.

Sewer and drain air differ but little in offensiveness, such differences as exist being of degree rather than of kind. The air from pipes conveying waste matters from water-closets, urinals, slop sinks, wash-up sinks, baths, lavatory basins, and other fitments used for similar purposes is likewise the cause of offence owing to the decomposition of organic filth on the interior surfaces. As a fact the interior condition of such pipes is often much worse than the drains into which they discharge.

In this connexion it is interesting to observe the view stated in the report of the Departmental Committee[2] previously referred to, viz. 'There seems to be no doubt that untrapped waste pipes of sinks and lavatories, discharging

[1] *Report of the Departmental Committee on Intercepting Traps in House Drains*, 1912, pp. 21 and 42.

[2] Ibid., p. 21.

into the open air, even those which are of short length, may be the cause of serious nuisance inside the dwelling, and that such pipes, on this account, need to be provided with efficient traps close to the fittings to which they belong.'

From the foregoing it may be deduced that the offensiveness of air from the named sources alone makes it essential to adopt precautions for preventing its emission in positions where nuisance may be experienced. It is unnecessary to establish its dangerous character, but if in addition to being offensive such air is also either productive of definite ill-health or the conveyer of direct infection, the necessity of adequate precautions becomes of still greater importance.

Emission of Air from Sewers, Drains, and Pipes Conveying Foul Matters

The most noted opportunities for the discharge of sewer air into the atmosphere are exposed outlets and ventilating openings, either at the ground level or in the form of ventilating pipes or shafts, and its passage through defective joints, pipe walls, &c., into the soil and thence as ground air into the atmosphere.

From drains (which include waste pipes from fitments, &c.), air finds its way through defective pipes, joints, and untrapped openings—including those provided for ventilation. Cesspools are responsible for much atmospheric pollution by the air discharged from relatively low-down ventilating pipes and the soakage of sewage into the soil where it contaminates the ground air which eventually mixes with the atmospheric cloak.

All too frequently the provision of a ventilating pipe or shaft to a sewer or drain is looked upon as sufficient to obviate the occurrence of nuisance. The mechanical provision of such pipes carried to a stated height above the ground or buildings does not, however, carry with it exemption from nuisance.

Prevention of Nuisance

The necessity of preventing emanations from sewers and drains is recognized by the Public Health Acts and by-laws made thereunder. Generally, it is an offence [1] to sweep, rake, or place any soil, rubbish, or filth into a sewer or drain, or to allow mud and offensive and dangerous matters (including steam, petroleum, and carbide of calcium) to pass into sewers or communicating drains. The washing or carriage of soil or refuse from any lands abutting upon any street into a sewer or gully so as to cause a chokage is also specifically prohibited.

Drains so foul or in such a state as to be a nuisance or injurious to health can be dealt with summarily as a nuisance. Moreover, in any case where a sanitary authority is satisfied that a drain or cesspool is in bad order or condition or requires cleansing, alteration, or amendment, steps must be taken to apply a remedy.[2]

Drains should be of sound construction and both air- and water-tight; laid to a sufficient and equable fall without tumbling bays or other vertical drops affording opportunities for the splashing of sewage, and so as to be self-cleansing; with adequate flushing arrangements when required to prevent silting up; with all inlets trapped and access openings covered; without low-down ventilators, and with effectual means of ventilation arranged in respect of position and height so as to provide a safe outlet for foul air.

The 'Trapping' of Inlets to Drain, Soil, and Waste Pipes

There is only one method of effectually preventing the escape of foul air from the inlet end of a pipé conveying

[1] See the Metropolitan Police Act, 1839; Metropolis Management Act, 1855; Public Health (London) Act, 1891; London County Council (General Powers) Act, 1894; and the Public Health Acts, 1890 and 1925.

[2] Metropolis Management Act, 1855; Public Health Act, 1875; and Public Health (London) Act, 1891.

offensive matters, and that is the provision of a 'trap'; of which types for varied positions are described and illustrated in Chapter XIII.

By-laws governing the construction of drains and sanitary fitments usually provide for (*a*) the trapping of all sewage drain inlets, including inlets receiving rain-, surface- or subsoil-water; (*b*) the provision of a trap immediately beneath soil and waste-water fitments; and (*c*) the fixing of an intercepting trap between drain and sewer. Suggested requirements[1] are:

Drains

Inlets to drains to be trapped. Every inlet, other than a ventilating pipe, to be properly trapped by a suitable and efficient trap so constructed and fixed as to be capable of maintaining a water seal of at least 2 in.

Soil fitments

(1) *Water-closets.* A suitable and efficient trap of lead, iron, glazed stoneware, or other equally suitable material to be fixed immediately beneath the soil-pan or basin and so constructed as to be capable of maintaining a water seal of at least 2 in.

(2) *Slop sinks and urinals.*

Trapping of waste pipes. Every waste pipe to be trapped immediately beneath the slop sink or urinal, by a suitable and efficient trap so constructed and fixed as to be capable of maintaining a water seal of at least 2 in., such trap to be constructed of lead, copper, iron, glazed stoneware, or other equally suitable material, with adequate means for inspection and cleansing.

Provided that where two or more urinal basins or stalls are fixed in a range such basins or stalls may discharge without the interposition of a trap into a semi-circular and accessible open channel of glazed stoneware or other equally suitable material fixed or formed in or on the floor immediately beneath or in front of such

[1] These requirements are based on *Drainage by-laws made by the London County Council under section 202 of the Metropolis Management Act,* 1855, *and the Metropolis Management Acts Amendment (By-laws) Act,* 1899; *and by-laws made by the London County Council under section* 39 (1) *of the Public Health (London) Act,* 1891, *with respect to water-closets, &c.*, and amendments now under consideration. The named by-laws do not apply to the City of London.

basins or stalls, but not extending laterally beyond such range, and discharging into a suitable and efficient trap as described above.

Waste-water fitments—Baths, bidets, lavatory basins and sinks

Trapping of waste pipes. Every waste pipe to be trapped immediately beneath such fitment by a suitable and efficient trap so constructed and fixed as to be capable of maintaining a water seal of at least 1½ in., such trap to be constructed of lead, copper, iron, glazed stoneware, or other equally suitable material, with adequate means for inspection and cleansing; provided always (i) that where two or more baths or lavatory basins are fixed in a range the waste pipes may discharge, without the interposition of a trap, into a semicircular and accessible open channel of glazed stoneware or other equally suitable material fixed or formed in, on, or above the floor immediately beneath such baths or lavatory basins and discharging into a suitable and efficient trap constructed and fixed as described above; and (ii) that the waste pipe of any sink fixed in an outbuilding not approached directly from an occupied building need not be trapped if such waste pipe does not exceed 3 ft. 6 in. in length and discharges into a suitable and efficient sewage drain trap constructed and fixed as above (see 'Drains').

Intercepting Traps

The question whether an intercepting trap between drain and sewer is necessary aroused some years ago so much discussion that in 1908 the Departmental Committee to whose report[1] attention has been drawn was appointed to inquire and report with regard to their use in house drains. The question is still much to the fore and both opinions and practice vary in regard to provision or non-provision of the trap.

Trap abolitionists suggest that (*a*) sewer air is no more offensive than drain air and consequently no differentiation need be made, (*b*) the trap is the cause of many blockages, (*c*) seriously interferes with the ventilation of

[1] *Report of the Departmental Committee on Intercepting Traps in House Drains*, 1912.

the sewer, (*d*) necessitates means of access to the trap and the provision of a fresh-air inlet to the drain, which inlet—by acting as an outlet—causes nuisance, and (*e*) complicates and increases the cost of drainage.

Protagonists of the trap submit that (*a*) the air of sewers is offensive and should be excluded from house drains, and that this is satisfactorily effected by the provision of a trap, (*b*) a trap prevents the passage of rats from sewer to drain, and (*c*) in the absence of a trap the weaker seals of drain or fitment traps inside a building may be forced by air-pressure from the sewer.

The Departmental Committee formed conclusions on many of the issues and points raised, but on the main question, i.e. the necessity or non-necessity of the trap, failed to give a definite lead. The effectiveness of the trap as a barrier to the passage of air from sewer to drain and the importance of preventing offensive emanations were fully recognized; but, inasmuch as the circumstances giving rise to nuisance (such as the existence of old and foul sewers) varied in different localities, the question of deciding whether a trap is or is not required in any locality or part of a locality is one 'to be considered and determined by the local authority and their advisers, in the light of local conditions'.[1]

The Minister of Health is now prepared to approve a code of by-laws omitting any reference to intercepting traps where drainage is to a sewer, but requiring such traps where the drain discharges to a cesspool; a differentiation that can only be justified in practice where the sewer net is so constructed as to be non-retentive of sewage matters, for storage sewers and sewers retaining sewage by reason of inadequate fall or faulty construction may be quite as productive of nuisance as cesspools.

A suitable by-laws specification[2] is as follows:

[1] *Report of the Departmental Committee on Intercepting Traps in House Drains*, 1912, p. 46.

[2] See footnote on p. 210.

Drains to be trapped from sewer. Every drain shall be provided with an intercepting trap at a point in such drain as near as practicable to the connexion of such drain with the sewer. Such trap shall be suitable and efficient, provided with a raking or clearing arm fitted with a secure and suitable stopper as a means of access to the drain between such trap and the sewer, be so constructed and fixed as to be capable of maintaining a water seal of at least 2 in., and provided with a manhole or other means of access sufficient for the purpose of clearing.

The 'Water Seal' of a Trap

A trap is designed with the object of preventing the escape of air from a pipe to the outer air—an object effected by a 'water seal'. The body of the trap contains a quantity of water the upper layer of which is divided into two distinct volumes and surfaces by a 'dip', i.e. a structural portion of the fitting which dips into the water and determines the depth or strength of the water seal or water barrier between the inlet and the outlet. For waste pipe traps this seal should not be less than $1\frac{1}{2}$ in., and for traps attached to pipes and drains conveying faecal matter 2 in.

The seal is maintained *in statu quo* by the equal pressure of the atmosphere on the inlet and outlet water surfaces. Should this equilibrium be disturbed some or all of the water may be forced out of the trap and the seal thus reduced or abolished. Such a disturbance is not uncommon and is brought about by the known influences of siphonage, momentum, and oscillation and waving-out due either to the pressure or expansion of gases.

Siphonage is effected by reducing the atmospheric pressure on the surface of the water at the outlet. It is most usual where two or more fitments on different stories of a building are connected to a single pipe, in which case a discharge from an upper fitment is liable to 'drag' out sufficient air from one or more of the lower branches, to create a partial vacuum and allow the contents of the trap or traps to be pushed out by the atmospheric pressure

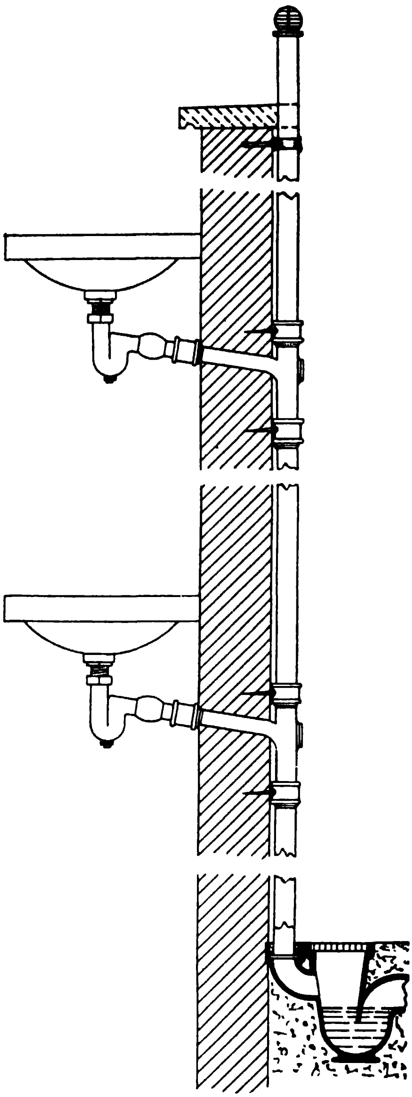


FIG. 102. Lavatory basins connected to a main waste pipe without trap-ventilating or anti-siphonage pipes.

exerted on the surface of the water in the trap inlet. Similarly, on discharging the bottom or intermediate fitments the traps above and/or below may be affected. Even where only a single fitment is connected to a pipe this action may take place, sufficient air being pushed out of the pipe by the flowing water to allow of siphonage.

Momentum is set up by the rapid discharge of a volume of water, such as on emptying the contents of a pail, the velocity of the outflow being such that before its arrestation a sufficiency of the normal trap content may be carried into the pipe to weaken or abolish the seal.

Oscillation of the contents of the trap is principally brought about by alternation of pressure on the water surface. With a pipe having several connected fitments a discharge from an upper fitment may force air into the branches below with sufficient pressure to drive the water in the outlet of the trap up into the inlet. On cessation

of the flow the pressure is removed, allowing the water to fall back into the trap so rapidly that a quantity may be waved out into the pipe, the amount of loss being determined by the pressure applied. Oscillation and waving-out can similarly be produced by the pressure arising from wind blowing down the pipe, by compression from the expansion of gases in pipes connecting with a sewer or cesspool, and by the backing-up of sewage from a sewer or cesspool in a drain and the compression of the air between the sewage and the trap, in each case the water in the trap being pushed up into the inlet, withdrawal of the pressure resulting in reaction and waving-out.

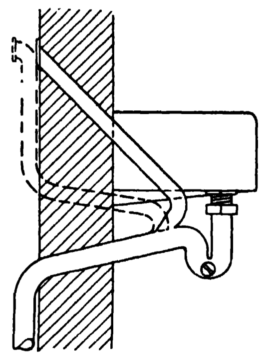


FIG. 103. Waste pipe of sink with trap ventilated by a 'puff' pipe.

The water content of traps attached to fitments and drains is liable to evaporate, and it is therefore essential if the traps are not frequently receiving waste liquids that they shall be periodically flushed out and recharged.

Ventilation of Pipes and Traps

Ventilation is the preventive of and the remedy for the phenomena just described. A free and frequent circulation of air through all pipes conveying foul matters is requisite to prevent the accumulation of gases which cause offence, and a rapid and adequate inflow of air as close to the outlets of traps as practicable to prevent siphonic action.

With a short branch joining a ventilated main or vertical pipe siphonage may not happen, but if the trap is joined to a long branch pipe siphonage may occur notwithstanding that such ventilation is provided. This is especially so where there is a considerable distance between the branch connexion and the top of the ventilating

pipe, by reason of such retardation—by friction against the interior surface of the pipe—of the air flowing down the pipe as to allow siphonic action to be set up before the air driven out by the flowing water can be replaced. It is therefore advisable to provide a supply of air close to the trap outlet by what is technically described as a trap-ventilating or anti-siphonage pipe.

To prevent siphonage of a single trap under a waste-water fitment it is sufficient to connect a ventilating pipe close to the outlet as in Fig. 103 and carry to a position

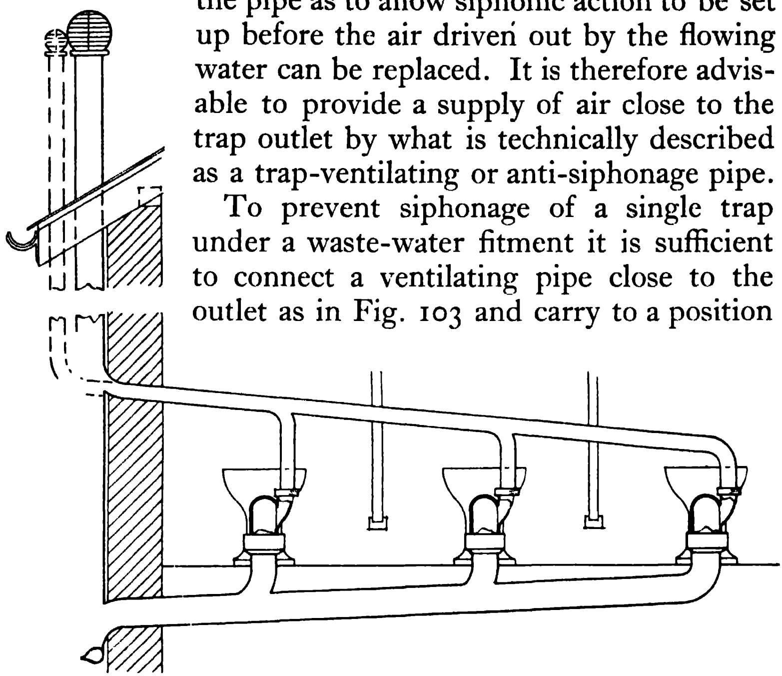


FIG. 104. Diagram showing range of water-closets with trap-ventilating pipes.

where foul air can safely be discharged. Such pipe is usually described as a 'puff' pipe.

Where two or more water-closet or slop sink fitments on different stories of a building connect with a single pipe the trap seals are always liable to be affected, and consequently trap ventilation is essential in addition to the ventilation of the main pipe. The trap-ventilating pipes may be carried up independent of and to the same height as the main ventilating pipe—which is advisable where the height of the pipe above the topmost fitment is considerable—or connected to the main ventilating pipe above the topmost fitment. Soil pipes (which expression includes waste pipes from slop sinks and urinals) should be

continued up as ventilating pipes to a height and position affording a safe outlet for foul air.

Figs. 102 and 105 respectively illustrate waste-water fitments without and with trap ventilation, and Fig. 104 the main- and trap-ventilating pipes for a range of water-closets on one floor.

Doubt is sometimes expressed as to whether ventilation of a main waste pipe taking the discharge from baths, sinks, and lavatory basins with the foot of the pipe disconnected from the drain is essential. Many experiments conducted by the author have proved this necessity, for in the absence of such ventilation siphonage has been the rule. Further, it is sometimes suggested that, even if particular traps are unsealed, such unsealing is very often but momentary and is remedied by drainings from the fitments, and in any case is not so material as with soil pipes, inasmuch as the waste pipes are not directly connected to the drain. The answer is that in many circumstances traps connected to the waste pipe other than the one in actual use are affected—maybe in a dwelling in separate occupation—and such traps would not be immediately recharged by drainings; and that commonly the interior of waste pipes is sufficiently foul to cause nuisance.

Trap ventilation for waste pipes from the fitments named is not always obligatory, for here experimental work indicates that where the main waste pipe is effectually ventilated there is less likelihood of trap siphonage than is seen with water-closets and slop sinks, a difference due to the smaller and less rapid discharge of waste liquids from the former. The results, however, depend largely upon the diameter of the waste pipe and the strength of the trap seal. Traps with $\frac{5}{8}$- to $1\frac{1}{4}$-in. seals are easily siphoned, whereas traps having a seal of not less than $1\frac{1}{2}$ in. may withstand such action although the sizes and general arrangement of the waste and ventilating pipes are identical. No golden rule can be laid down, and the omission of trap-ventilating pipes where sinks and baths have large-

diameter outlets would be an error of judgement. To be on the safe side it is best to provide for ventilation in all

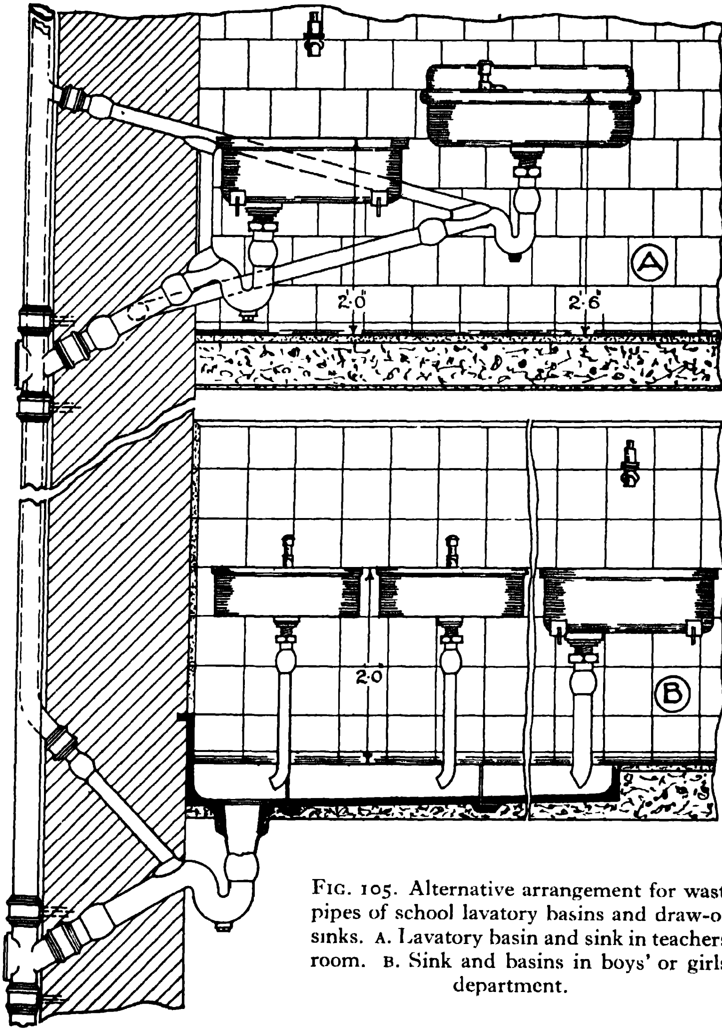


FIG. 105. Alternative arrangement for waste pipes of school lavatory basins and draw-off sinks. A. Lavatory basin and sink in teachers' room. B. Sink and basins in boys' or girls' department.

cases where more than one fitment is connected to a waste pipe.

Drain ventilation, to be efficient, should provide for a circulation of air throughout the entire system, and for

the escape and diffusion of foul air in positions where nuisance is unlikely. The provision to be made depends, in ordinary circumstances, on whether an intercepting trap is provided. Without such a trap, on a simple system of drainage, one ventilating pipe at the highest point is sufficient. With a trap, a second opening is necessary communicating with the drain as near to the trap as practicable.

For extensive systems with long branches additional means of ventilation are required; and where the drains are sectionized by the insertion of reverse-action intercepting traps at least two ventilating openings are requisite for each section.

The usual practice with a simple system, and one commonly required by by-law, is a low-down opening intended to act as an inlet, and an upcast or outlet pipe at opposite ends of the drain, the relative positions of the inlet and exhaust depending upon circumstances. Alternatively, two pipes may be provided, both carried to a height and position allowing for safe diffusion of foul air.

Although low-down openings are intended to act as fresh-air inlets, owing to variable atmospheric conditions they frequently act as outlets for foul air and thus allow its dissemination in positions causing much nuisance. Consequently their use should be restricted to places away from occupied buildings where foul air can be diffused with safety.

Soil pipes suitably positioned may be utilized for drain ventilation. If such pipes are not available, specially provided means are often compulsory.

All pipes intended for ventilation should have full-way openings to the outer air, merely protected against the entry of substances liable to cause obstruction by plain gratings or wire balloons, having orifices not less in area than those of the pipes to which they are attached. Fresh-air inlets of the valve type are seldom operative in the manner intended and are unnecessary for pipe openings

properly situated as above mentioned. The use of cowls is also deprecated, as they more often impede than assist air-movement through pipes.

Pipes should be as free from bends as possible, and iron pipes intended solely as ventilators ought to be fitted with a rust pocket—similar to Fig. 125—at the base.

Size of Ventilating Pipes

Soil and waste pipes should be continued upwards as ventilating pipes without diminution of the internal diameter. Soil fitments should have trap-ventilating pipes of a minimum internal diameter of 2 in. If a $2\frac{1}{2}$- or 3-in. trap-ventilating pipe is fixed in connexion with a $3\frac{1}{2}$- or 4-in. soil pipe the latter will take without risk of siphonage a larger number of fitments than where a 2-in. diameter pipe is provided.

The branch and main trap-ventilating pipes attached to baths, sinks, and lavatory basins should not be less than two-thirds of the respective internal diameters of the branch and main waste pipes, with a minimum of 1 in. 2-in. trap-ventilating pipes may be accepted as ordinarily sufficient for 3-in. and larger diameter main waste and ventilating pipes.

A 4-in. diameter pipe is large enough for drains up to 6 in. in diameter. In districts where a $3\frac{1}{2}$-in. soil pipe is permissible such pipe is often accepted for the ventilation of the drain.

The following may be accepted as an epitome[1] of the by-law requirements in respect of the ventilation of drains, traps, soil and waste pipes:

Drains

(1) If an intercepting trap is provided, at least two ventilating pipes should be provided to the drain, one connected to the drain at a point as near as practicable to and on the inlet

[1] See footnote on p. 210.

side of the intercepting trap, and the other at a point as far distant as practicable from the intercepting trap.

(2) If an intercepting trap is not provided, at least one ventilating pipe should be provided, connected to the drain at a point as far distant as practicable from the sewer to which the drain is connected.

(3) Every such pipe should be carried up vertically to such a height and position as to prevent any nuisance or injury or danger to health arising from the emission of foul air from such a pipe.

(4) Every such pipe should have an internal diameter of not less than $3\frac{1}{2}$ in., be securely fixed without unnecessary bends or angles, be constructed in the same manner and of the same material and weight as if such pipe were a soil pipe or a soil-ventilating pipe, and be furnished at the foot thereof with a suitable air-tight access cap or cover.

(5) The soil pipe or ventilating pipe of any water-closet, or the waste pipe or ventilating pipe of any slop sink or urinal, where the situation and sectional area are in accordance with the requirements applicable to the pipe to be carried up from the drain, may be deemed to provide the necessary means of ventilation.

Soil pipes and waste pipes from soil fitments (*i.e. slop sinks and urinals*)

The pipe should be circular, have an internal diameter of not less than $3\frac{1}{2}$ in., be securely fixed without unnecessary bends or angles, and continued upwards without diminution of its diameter as provided for in paragraph (3) above.

Traps of soil fitments

If the soil pipe or waste pipe of any soil fitment, that is to say, any water-closet, slop sink, or urinal is in connexion with any other such fitment, the trap of every fitment should be ventilated into the open air at a point as high as the top of the soil-ventilating pipe or waste-ventilating pipe, or into the soil-ventilating pipe or waste-ventilating pipe at a point above the highest fitment.

The branch and main ventilating pipes respectively from such fitments should have in all parts an internal diameter of not less than 2 in. where connected with a soil pipe, or with a waste pipe

3 in. or more in internal diameter, and not less than two-thirds of the respective internal diameters of the branch and main waste pipes where the internal diameters of the pipes are less than 3 in.

The ventilating pipe should be connected with the branch soil pipe or waste pipe or the trap at a point not less than 3 nor more than 12 in. from the highest part of the trap and on that side of the water seal which is nearest to the soil pipe or waste pipe, and in the direction of the flow.

Waste pipes from baths, bidets, lavatory basins and sinks

Where any waste pipe is connected with two or more such fitments fixed on different stories of a building it should be continued upwards without diminution of its diameter, and without unnecessary bends to a height and position as provided for in paragraph (3) above.

Traps of waste fitments

In order to preserve the seal of the trap of any such fitment the trap should be ventilated whenever necessary by a ventilating pipe carried to a position as provided for in paragraph (3) above; and where the pipe is connected to the traps of two or more such fitments fixed on different stories of a building, it should be carried up as high as the top of the waste-ventilating pipe or into the waste-ventilating pipe at a point above the highest fitment.

The branch and main ventilating pipes respectively from the trap should have an internal diameter of not less than two-thirds the respective internal diameters of the branch and main waste pipes; provided that the internal diameter of the ventilating pipe should not be less than 1 in. and provided also that where the waste pipe exceeds 3 in. in internal diameter the internal diameter of such ventilating pipe need not be greater than 2 in. The ventilating pipe should be connected with the branch waste pipe or the trap at a point not less than 3 nor more than 12 in. from the highest part of the trap, and on that side of the water seal which is nearest to the waste pipe, and in the direction of the flow.

XIII

TRAPS AND FITTINGS

THE object of 'trapping' pipes used for the conveyance of offensive matters is explained in Chapter XII, from which it may be inferred that the all-essential feature of a trap is the sufficiency of the water seal intended to form a barrier against the escape of foul gases. Other essential features are the limitation of the size to that required for the passing of the waste matters, and a shape that is self-cleansing, i.e. without angles or voids favouring the accumulation of substances and gases.

Unsuitable Traps

Many of the traps of early design fail to meet the standard arrived at by experience and are no longer accepted as efficient or suitable. Of these the 'D', bell, and lip traps, and the dip or mason's trap are forms now almost universally condemned and excluded from use by by-law. Other bad forms, though not singled out or prohibited by name, come under ban as unsuitable. These include bottle traps, and several forms of mechanical traps fitted with hinged flaps on the outlet or loose balls intended to cover the inlet or outlet and constitute a secondary precaution against the escape of gases from the attached pipe. Such mechanical attachments or devices seriously impede the free discharge of waste matters, frequently get out of order, and are quite unnecessary except in very special circumstances where intended for use as preventives against the backing-up of sewage from the drain through the trap to the outer air. (See p. 232.) As a guiding principle a water seal alone should be depended upon.

Although most of the traps named are now more or less relics of the past, there are yet many indifferent patterns available and used, such as fitment traps with an insuf-

ficient water seal, and gully and intercepting traps of bad shape, too large a content, or without a proper fixing base.

'Suitable' and 'Efficient' Traps

The Model[1] by-laws require fitments and drains to be 'properly' trapped, while certain other by-laws[2] specify suitable and efficient traps so constructed and fixed as to

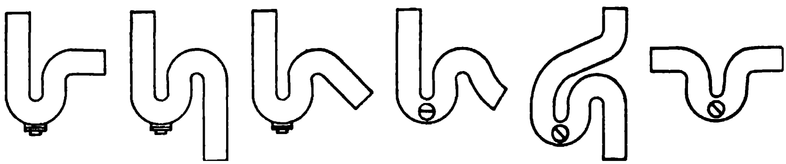


FIG. 106. Traps for fitments. 'P' 'S' '¾S' 'Q' 'Bag' 'Running'.

be capable of maintaining a water seal of 2 in. where used for drains and soil fitments, and 1½ in. for waste-water fitments.

To meet the expression 'suitable and efficient', traps for ordinary use should, in addition to such water seal, embody the following qualifications: (*a*) be of self-cleansing round-pipe shape; (*b*) contain as small a quantity of water as is consistent with the maintenance of the seal and the use to which the fitting is to be put; (*c*) have an inlet larger than the outlet and a throat smaller than the latter so as to accentuate 'scouring'; and (*d*) be made of a non-porous substance with a smooth internal surface offering the least resistance to the flow of the discharging matters. Traps intended for special purposes—such as grease interception—cannot be expected to comply with (*a*) and (*c*), and these traps must be judged by their effectiveness and suitability.

Classification of Traps

Traps may, for convenience of description, be placed in one of two categories, viz. (1) round-pipe traps for fitments, and (2) drain traps.

Urban, Series IV, 1925. [2] See footnote on p. 210.

Round-pipe traps for fitments.—Round-pipe traps are made in lead, copper, brass, gunmetal, iron, glazed stoneware, and enamelled earthenware, of the shapes shown in Fig. 106, i.e. as 'P', 'S', '¾ S', 'Q', 'bag', and 'running' traps, excepting stoneware and earthenware, the shapes in these cases being, as a rule, restricted to 'P' and 'S'.

A variation of the round-pipe trap is the Anti-D trap, which is designed to prevent siphonage and momentum by means of an enlarged air space in the form of a squared outgo.

Lead traps are either drawn or cast. The former are generally quoted of a thickness corresponding with sheet lead as in Table No. II. The trap should be at least equal in thickness to the pipe with which it is to be connected.

TABLE No. II, *showing the thickness of walls and the strength of drawn-lead traps compared with sheet lead.*

Internal diameter	1¼ *in.*	1½ *to* 4 *in.*	4½ *in.*	*Thickness of walls in decimals of an inch.*
Weights compared with sheet lead in lb. per sq. ft.	4½	—	—	0·075
	—	5	—	0·084
	6	6	6	0·101
	7	7	—	0·118
	8	8	8	0·135
	—	10	10	0·170

Cast-lead traps, bends, and junctions are manufactured in the substance of 8 to 10 lb. lead and have the advantage of being stronger than those made of drawn lead. Lead traps are in common use, the only objection of note being their unfitness for rough usage.

Cast- or drawn-copper, *brass*, *and gunmetal traps* can be had fitted with unions on both inlet and outlet. If of drawn metal the minimum thickness should be as given for pipes in Table No. XIII, Chapter XVI, p. 291. For exposed positions where appearance is of moment, a polished, nickel plated, or enamelled finish is acceptable.

Cast-iron traps for baths, sinks, and lavatory basins are available with the inlets and outlets screwed for connecting

to wrought-iron waste pipes or to unions wiped on to lead, or with a beaded spigot for caulking into iron sockets. The metal can be galvanized or bituminous coated throughout, vitreous enamelled inside with the outside either porcelain enamelled or coated with bitumen or metallic paint. The best treatment is vitreous enamel inside, which gives a smooth finish, with porcelain enamel or a bituminous coating outside.

A defect common to many brass and iron bath traps is the meagre depth of the water seal, which in some cases is only $\frac{5}{8}$ or $\frac{3}{4}$ in.

Cast-iron traps are sometimes fitted to ware water-closet basins, and to urinals and slop sinks, the trap being bituminous coated throughout, or outside only, with the inside either glass or porcelain enamelled.

Glazed stoneware and enamelled earthenware traps in pipe form are used for water-closets where the pan and trap are in two pieces; also for slop sinks, urinals, and domestic sinks. The difficulty, however, of securing adequate fixing and an effectual joint renders them far less suitable for domestic sinks than either lead or iron. For laboratory use salt-glazed stoneware traps are largely used owing to their acid-resisting quality.

Drain traps are made either in heavy cast-iron, salt-glazed stoneware, or enamelled ware, of varied shape and intended for various positions and uses. If of iron they should be coated both inside and outside with Dr. Angus Smith's solution. This applies to all iron fittings, unless galvanizing or other suitable process described in Chapter XIV, p. 251, is adopted.

An extensive range of traps, in iron, stoneware, and fireclay, is open to selection.

Disconnecting Traps for Waste-water Fitments and Rain and Surface Water

Figs. 107 and 108 illustrate cast-iron 'Adapta' gully traps in two parts, permitting the use of various pattern top

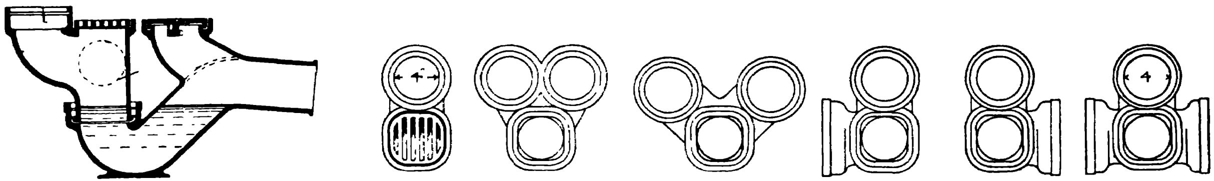


Fig. 107. Cast-iron 'Adapta' gully trap with one-, two-, or three-branch inlet pieces and means of access to drain.

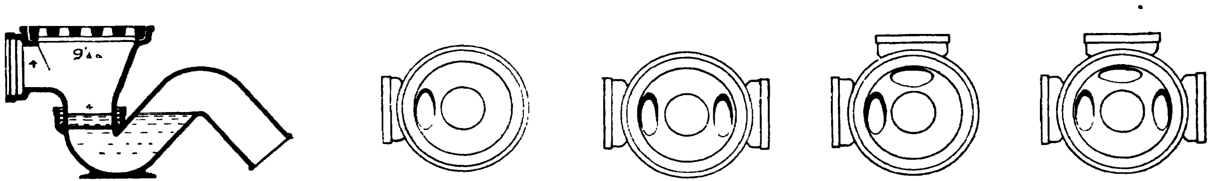


Fig. 108. Cast-iron 'Adapta' gully trap with enlarged inlet for one, two, or three waste pipes.

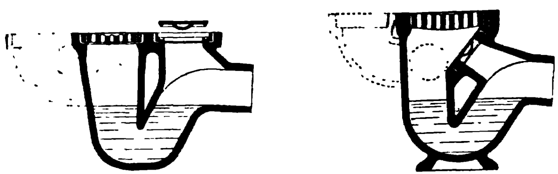


Fig. 109. Doulton's stoneware gully traps with means of access to drain.

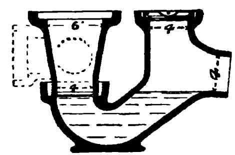
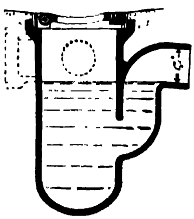


Fig. 110. Doulton's reversible stoneware gully trap with hopper inlet and means of access to drain.

pieces having vertical and/or side or back inlets. Fig. 107 is provided with an access cap to drain.

Figs. 109 and 110 show stoneware gully traps, each having an inspection eye with galvanized-iron sealing plate fitting with tongue-and-groove grease joint into a fixed galvanized frame and secured by gunmetal screws.

These traps can be fitted with a sealed cover, or a plain, locking, or hinged and locking grating.



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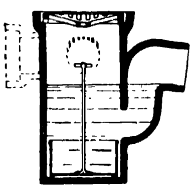

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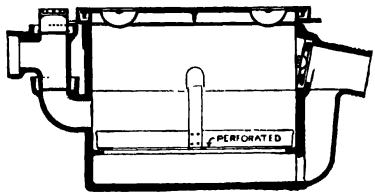


113

FIG. 111. Doulton's deep glazed stoneware yard gully trap with hinged grating.

FIG. 112. Doulton's glazed stoneware yard gully trap with wrought-iron silt bucket.

FIG. 113. Doulton's 'Improved Grease Interceptor' with sealed cover, galvanized-iron tray, and means of access to drain.

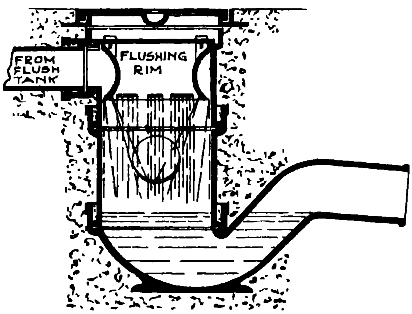
Special Traps for Surface Water

For the reception of surface water, drainage from stables, &c., the ordinary self-cleansing type is often unsuitable, as heavy solids are carried through it into the drain, where silting up may take place. A form of trap—as in Figs. 111 and 112—which will arrest sand, mud, and other substances is therefore preferable.

Grease Traps

Greasy water from wash-up sinks is a source of much trouble when discharged into a drain without special precautions, for the grease coagulates as a 'cheesy' substance, adheres to the interior of the pipes and brings about a stoppage. To prevent this two methods can be employed: (1) the discharge of the waste water into a grease intercepting trap containing a volume of water sufficiently

large to coagulate the grease rapidly and allow of its deposit in the trap and removal by hand, and (2) the discharge of the water into a self-cleansing or flush-out trap receiving, from an automatic flushing tank, periodic discharges of clean water sufficient to break up the coagulated grease, scour the trap, and carry the entire contents away to the sewer or other means of disposal.



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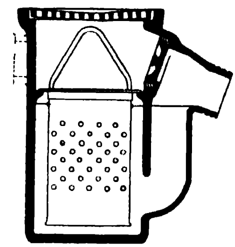


115

FIG. 114. Macfarlane's cast-iron flush-out grease trap with reversible inlet, flushing-rim, and locking cover.

FIG. 115. Doulton's glazed stoneware 'Garage' trap fitted with bucket and means of access to drain.

For the interception of grease, traps fitted with a bucket of the pattern shown in Fig. 112 are often used, but a special and better fitting is illustrated in Fig. 113. This trap contains a relatively large quantity of cooling water for coagulating the grease; a galvanized-iron sealing cover with rubber seating—an essential feature if the trap is fixed within a building and desirable in any position; means of access to the drain; a ventilating opening at the point of connexion of the waste pipe and the trap; and a perforated grease-collecting tray of galvanized-iron above the trap outlet for preventing solid matters from passing into the drain.

Fig. 114 illustrates a flush-out trap with a flushing rim. Another pattern (Hellyer's patent) is made of vitrified stoneware with single or double inlet connectors for waste

pipes, flushing rim, a jet inlet for breaking up the grease collecting on the surface of the water, and a bottom inlet for scouring out the solid matter.

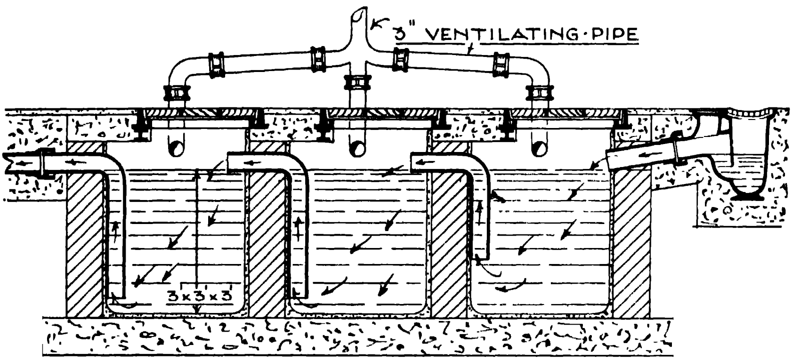


FIG. 116. Garage petrol-intercepting trap, based on London County Council specification.

Disconnecting and Intercepting Traps for Petrol Stores and Garages

To prevent the discharge of spilled petroleum oil or spirit into sewers a special intercepting trap is insisted upon by many local authorities. (See Chapter XXI, p. 392.) Fig. 115 illustrates Doulton's stoneware gully trap 12 in. in diameter and 24 in. in depth specially designed for motor garages to intercept oil, petrol, and silt. It is claimed that the deep seal retains the floating oil and spirit. This trap is also useful for retaining grease from wash-up sinks. Another useful fitting is Farrer's cast-iron gully trap fitted with a galvanized-iron bucket for intercepting sand and other detritus, and a second bucket to hold coke for intercepting heavy oil.

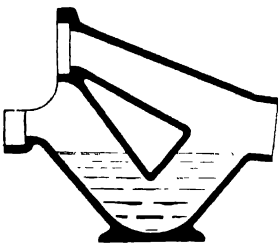
An intercepting trap of the type shown by Fig. 116 is prescribed in London.[1]

Intercepting Traps

Many patterns are made, varying in detail but all con-

[1] *Abstract of the Regulations as to the keeping, sale, conveyance, and hawking of Petroleum in the County of London.*

forming to a common standard of a trap intended for fixing in a line of drain with means of access to the section of drain connecting the trap outlet with the sewer or cesspool, &c.



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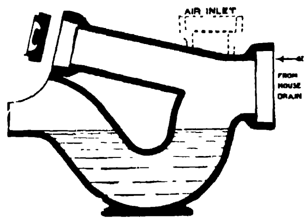


118

FIG. 117. Doulton's 'Salus' glazed stoneware intercepting trap.
FIG. 118. Doulton's 'Netley' reverse-action intercepting trap.

The traps are of two distinct types, viz. open traps for fixing in an inspection chamber with exposed channel lead, and sealed traps for fixing in, or independent of, a chamber.

The first is illustrated by Fig. 117, made in stoneware and embodying the best principles of construction, including a cascade inlet, the minimum content of water having regard to efficiency, a good seal, and a rectangular front enabling a sound and workmanlike connexion to the brickwork or concrete forming the chamber; and the second by Fig. 139, which shows a combined intercepting trap and chamber with sealed cover, and access to drain between trap and sewer.

Reverse-action Intercepting Traps

For sectionizing systems of drainage, securing effective means of ventilation to branch drains, intercepting rain and surface water drains from sewage drains, and, on occasion, reducing the number of inspection chambers, reverse-action traps as given in Fig. 118 are utilized. As may be seen, means of access and ventilation are provided to the inflowing drain.

Anti-flooding or Back-pressure Valves

For situations where sewage is likely to be 'backed up' the connected drains on charging of the sewers in time of storm, an effect most often produced in cellars and basements, an appliance is essential to prevent the exit of sewage through the traps and the flooding of the premises. Such appliances may take the form either of a flap or ball valve applied to the portion of the drain between the sewer and the intercepting trap, to the intercepting trap, or to the disconnecting (gully) traps at the inlet of the branch drains affected.

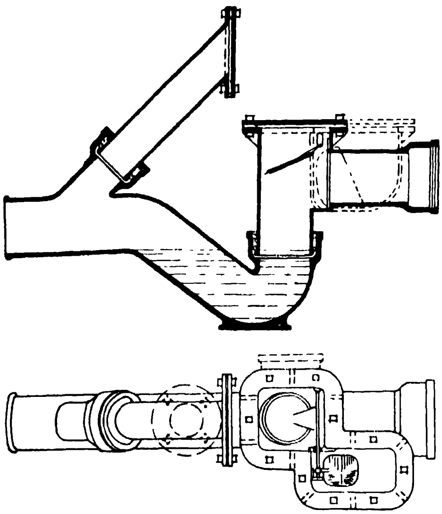


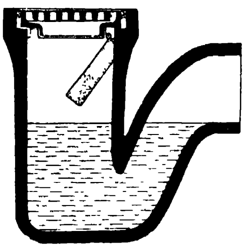
FIG. 119. Plan and section of 'Eureka' anti-flooding valve combined with intercepting trap.

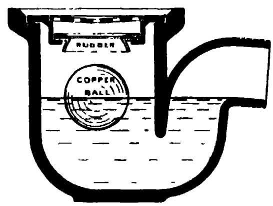
Fig. 119 illustrates a combination of an intercepting trap and a good hinged type of anti-flooding valve fitted with a bolted access cover, an aluminium valve, spindle, seating and bearings, a rubber disk and a japanned cork float. The valve hangs on a spindle in a chamber above the drain when the latter is working. On the backing up of sewage the float in the adjoining chamber rises with it and closes the valve. On recession of the sewage the float falls and thus reopens the valve. To secure effective operation a $\frac{3}{4}$-in. air vent-pipe should be fitted to the float chamber.

Fig. 120 shows an aluminium hinged valve with cork float closing against a rubber seating with cast-iron valve plate and frame for fixing in the rebate of a surface gully trap.

Fig. 121 illustrates a gully trap with a loose copper ball and a rubber seating for the ball to impinge against.

Reflux or flap valves are often fixed at the end of a drain at the point of connexion with a sewer for the purpose of preventing backing up of sewage and, incidentally, the passage of rats from the sewer to the house drain.





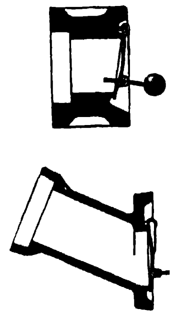


FIG. 120. 'Eureka' anti-flooding valve fitted to gully trap.

FIG. 121. Doulton's glazed stoneware ball-valve gully trap for prevention of back-flooding.

FIG. 122. Doulton's galvanized-iron flap-valves hinged to stoneware block and pipe connexions to sewer.

Fig. 122 illustrates galvanized-iron flap-valves hinged respectively to a stoneware junction block with a ground face and a pipe connexion; and Fig. 123 a reflux valve in iron with gunmetal machined faces, hinge bolt, and bushes, with means of access, for fixing in the line of a drain.

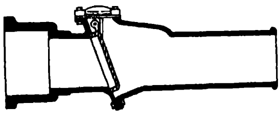
Access to Valves

The objection to all valves and flaps is the probability of being thrown out of action by the attachment of solid matters to the valve or seating, or want of attention to the working parts. Therefore means of access, regular examination, and maintenance in proper working order are essential to success.

Trapless Gullies

For rain- and surface-water drainage unconnected with a sewage system, or discharging into a properly trapped

sewage-drain inlet, trapless gullies are suitable. These fittings retain the silt and at the same time provide an untrapped opening for ventilating the length of drain. Fig. 124 illustrates a fitting suitable for use with various patterned tops, gratings, &c.



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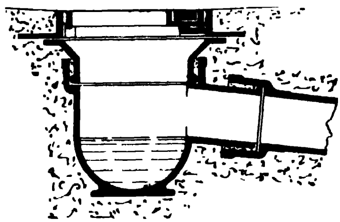

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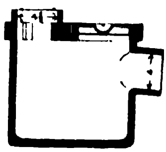

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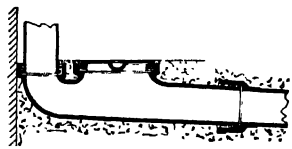

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FIG. 123. Cast-iron re-flux valve with means of access for fixing in line of drain.

FIG. 124. Macfarlane's cast-iron trapless gully with locking cover.

FIG. 125. Doulton's 'Rust Pocket' in glazed stoneware with galvanized-iron screwed sealing plate.

FIG. 126. Cast-iron rainwater shoe with sealed cover.

Rust Pockets or Interceptors

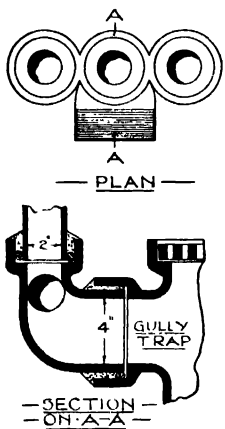
These fittings are often needed at the foot of rain-water pipes and drain-ventilating pipes. That shown in Fig. 125 is of stoneware with a galvanized-iron frame fixed in the rebated top, with sealing plate secured by gunmetal screws in a tongue-and-groove joint.

They are not wanted for drain-ventilating pipes where the latter are properly coated inside with Dr. Angus Smith's solution or otherwise protected against corrosion.

Rain-water Shoes

For receiving the discharge from pipes conveying rain-water from roofs trapless gullies or rust pockets can be utilized, or rain-water shoes similar to Fig. 126, always

provided that the connected drain does not discharge directly into a sewage system. Thus used, such fittings can be completed with a loose or locked grating which allows ventilation of the drain. For some premises, e.g.



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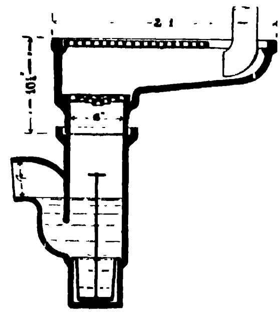

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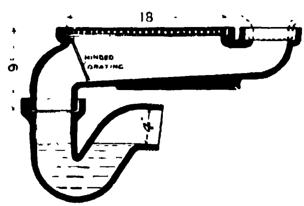

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FIG. 127. Three-way glazed stoneware connector for waste pipes and gully trap.

FIG. 128. Doulton's 'Open Channel' for waste pipes discharging into gully trap fitted with bucket.

FIG. 129. Doulton's 'Open Channel' for waste pipes discharging into self-cleansing gully trap.

schools, a sealed cover is required to prevent the insertion of foreign substances which would cause a stoppage.

Connectors

For connecting several waste- or rain-water pipes to a single trap so as to discharge below the grating, the connecting pieces in Figs. 107, 108, and 127 are useful.

Open Channels for Waste Pipes

In some districts the by-laws specify that waste pipes shall discharge in the open air over a channel leading to

a trapped gully grating at least 18 in. distant. To meet such a requirement a stoneware channel discharging below the grating as illustrated by Figs. 128 and 129 may be utilized.

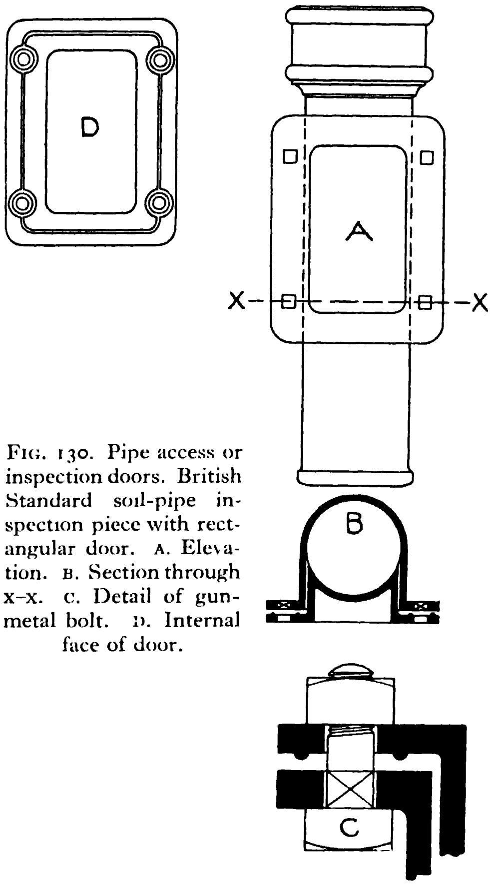


FIG. 130. Pipe access or inspection doors. British Standard soil-pipe inspection piece with rectangular door. A. Elevation. B. Section through X–X. C. Detail of gun-metal bolt. D. Internal face of door.

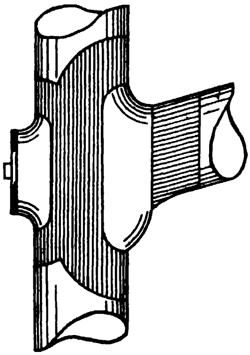
Access to Traps and Pipes

Facilities for access are advantageous in connexion with all traps, pipes, and fittings. By-laws [1] in particular areas require the traps of all slop sinks, urinals, bidets, sinks, baths, and lavatory basins to have adequate means for inspection and clearing, a requirement met by the provision

[1] See footnote on p. 210

of clearing screws on the side or bottom of the trap as in Fig. 106.

Access can be furnished to lengths of iron soil and waste pipes, bends, and junctions by inspection caps or doors. Fig. 130 illustrates a B.E.S.S. inspection piece with rect-



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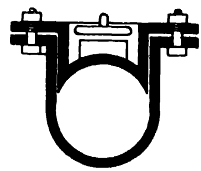

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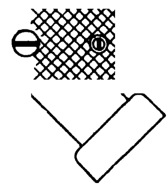

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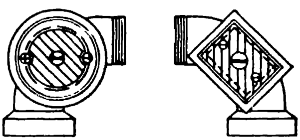


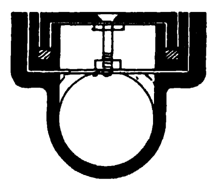


FIG. 131. Screwed access cap to lead soil-pipe.

FIG. 132. Section of cast-iron drain-inspection pipe cover.

FIG. 133. Plan and enlarged section of galvanized-iron access cover to glazed stoneware junction.

FIG. 134. Glazed stoneware inspection bends with screwed covers.

angular door. A greased felt or oil-dressed leather washer and galvanized-iron or gunmetal bolts and nuts should be used.

Lead pipes can be fitted with brass or gunmetal screw caps of the type shown in Fig. 131, the lining being wiped on to the pipe.

Cast-iron drain pipes, bends, and junctions can be fitted with an inspection door or cover with greased felt or oil-dressed leather washer fixed by galvanized-iron, brass, gunmetal, or manganese bronze bolts (Fig. 132); a wrought-

iron bridge or bridle with gunmetal pinching screw; or a hinged non-detachable door.

Stoneware pipes, bends, and junctions can be similarly provided with access openings fitted with frames and sealing plates or covers (Figs. 133 and 134).

In London[1] intercepting traps must be provided with a manhole or other means of access sufficient for the purpose of clearing, and with a raking or clearing arm as a means of access to the drain situated between the trap and the sewer. The Model by-laws[2] require proper means of access to such traps for the purpose of cleansing.

Intercepting Trap Stoppers

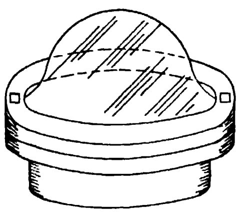
Too little regard is often paid to the type of stopper used for the raking arm of intercepting traps, which arm furnishes access to the length of drain between the trap and the sewer or cesspool. There are two factors of importance in the selection of the stopper, (1) prevention of the stopper being blown out by air-pressure in the sewer or forced out by the back pressure of sewage, and (2) provision for quick removal of the stopper should the drain become choked.

One of the commonest types used for stoneware traps fixed in inspection chambers is the 'Stanford', which has a tapered ring of bitumen similar to Fig. 158 fitting into a ring of the same material within the socket of the access pipe, grease being used for jointing; a stopper that is easily forced out on back pressure of air or sewage. Improved types for stoneware traps are the screw 'Stanford' stopper and the 'B.P.' These stoppers and the fitted sockets are provided with bitumen rings and, properly fixed, cannot be forced out by back pressure.

The disadvantage of all stoppers of the kind illustrated, should the drain become choked, is the necessity of removing the sewage from the inspection chamber so as to obtain access to the trap and the outlet drain. Preference

[1] See footnote on p. 210. [2] Urban, Series IV, 1925.

is therefore given by some engineers to the use of a glass plate or dome (Fig. 135), or a piece of slate which can be cemented or otherwise fixed in the socket, thus properly sealing off the drain, and yet can be broken from the ground level, so as to discharge the sewage content of the chamber.



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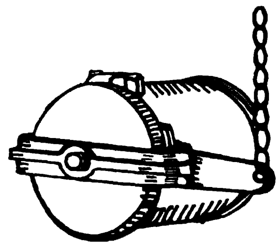


136

FIG. 135. Beattie's 'Glass Dome Stopper' for intercepting-trap clearing arm.
FIG. 136. 'Clencher' releasing stopper for intercepting-trap clearing arm, with machined faces, asbestos washer, lever handle and chain.

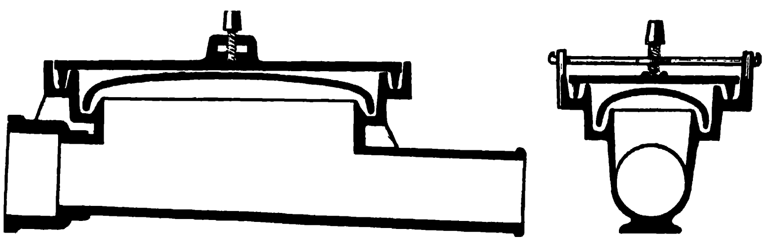


FIG. 137. Sections of cast-iron deep channel with double-seal cover, wrought-iron bridle, gun-metal screw and lifting rings.

Suitable fittings are the lever locking stopper having a frame cemented into the socket and a stopper-plate closing upon a leather seating held in position by a pivoted lever with a releasing chain carried to the top of the chamber, complete with handle and staple for attachment to the wall of the latter; and the 'Clencher' releasing stopper (Fig. 136) with asbestos washer which is applicable in slightly varied form to both iron and stoneware traps.

With totally enclosed drains of iron or stoneware the flooding of the inspection chamber is obviated, and any good lever or bridge pattern can be utilized; or, if

preferred for iron drains, a plate bolted on to flange of access pipe.

The stopper employed should be secure and suitable.

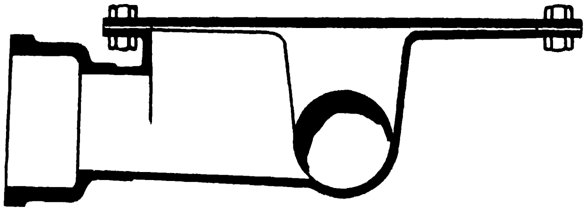


FIG. 138. Cast-iron inspection chamber with benchings, deep channel, and bolted cover.

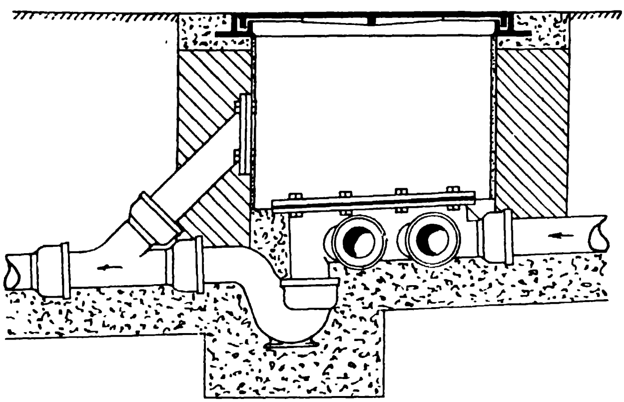


FIG. 139. Intercepting chamber with sealed cast-iron drain.

Inspection Chambers

Where several branch drains are connected to a main drain an inspection chamber is required, either sealed at the drain level, or open in the form of a brick or concrete manhole with exposed drain channel. (See Chapter XXI, p. 386, for 'open' manholes or chambers.) Fig. 132 illustrates a cast-iron channel chamber of pipe section without benchings and thus furnishing the minimum interior fouling surface; Figs. 137 and 138 sections with a deepened channel; and Fig. 139 a combined intercepting trap and inspection chamber.

Sealed stoneware channel chambers are not as a rule provided with more than two branch connexions. Cast-iron chambers of this type are commonly stocked with from one to six branches; special fittings taking a larger number being made to order. The standard angles of the branches are usually from 90° to 135°. Special fittings range, however, from 90° to 180°, with reverse branches

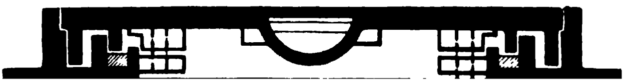


FIG. 140. Double-seal cast-iron cover with rubber sealing and gun-metal bolts.

from 80° to 0°. Both stoneware and cast-iron channel chambers can be had with a vertical outlet, thus adapting them for use with traps illustrated by Fig. 139.

Covers for Inspection Chambers

The channel chambers just described are designed for a totally enclosed system of drainage, and given the use of airtight covers of the types illustrated are suitable for exposed positions.

For manholes and inspection chambers iron covers fixed with screws, bolts, or a lock should be used, for the ease with which an unfastened cover can be lifted and improperly replaced is often responsible for its lack of air-tightness. All things considered, a screwed or bolted cover with a seating of greased felt, india-rubber, asbestos, or oil-dressed leather is the best. Fig. 140 illustrates a suitable pattern.

It is a reasonable suggestion that means of access to drains should be fitted with a suitable cover, and, if within or under a building, with a suitable screwed or bolted airtight cover fixed, where the access is in the form of a manhole, to the channel of the manhole.[1]

All covers and frames should be galvanized or coated with bitumen, and of sufficient strength to meet the traffic

[1] See footnote on p. 210.

needs. Where the finished appearance is of moment the covers can be recessed for concrete, asphalt, tiles, or wood blocks.

Bends and Junctions

Changes of direction in, and the connexion of branches to, a main soil or waste pipe are respectively made by the use of pipe bends and junctions. The same applies to drains where such change of direction or branch connexion is made without interruption of the sectional continuity of the pipe. Where the change of direction takes place, or the branch connexion is made, in an inspection chamber, pipe bends and junctions with means of access (Figs. 132, 133, and 134) may be used, or open channels and channel bends.

For iron soil and waste pipes, offsets or swan-necks, bends, and junctions with angles ranging from 90° to 157½° are usually stocked. Almost every required mode of branching and connecting is now provided for—short and long bends and offsets, bends with ventilating branches, junctions for parallel pipes, long and short branches, diminishing branches, double branches, equal or diminishing, and 'Y' or breeches junctions.

Similarly, iron drain-pipe bends and junctions are made to meet most positions. Bends and junctions with angles of 90° to 160° range from 'sharp' or 'knuckle' bends to sweeping bends varying in radius from 2 ft. 6 in. to 12 ft. Tapered bends increasing or decreasing to the outlet end; junctions with unequal faucets or sockets and spigots; and reverse bends from 45° to 85° are also available. Soil- and drain-pipe bends can also be had with a heel or duckfoot rest for fixing at the base of a vertical pipe.

Less diversity is seen with stoneware fittings, which are mostly made in ¼, ⅙, and ⅛ circle or radius as 'knuckle', 'medium', and 'easy' bends. Bends of 4 in. diameter and $\frac{1}{16}$ circle are, however, obtainable. Stock junctions are square, oblique, and curved oblique—single or double. Bends tapering either to inlet or outlet are procurable, also bends with a rest or foot.

Channels and Channel Bends

Open channels and channel bends in iron are generally of half-pipe section and either coated throughout or coated outside and glass or porcelain-enamelled inside. Stoneware channels and channel bands can be either half or three-quarter section.

An improved pattern is the white enamelled or brown salt-glazed Doulton 'square face' bend which is so curved

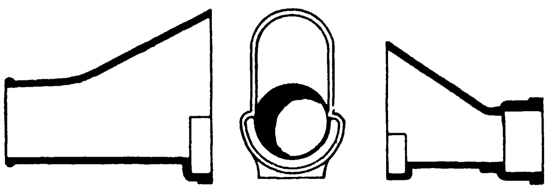


FIG. 141. Drain chutes in cast-iron.

and modelled as to turn the flow of the sewage in the most efficient manner in the direction of the main channel, on the edge of which the rectangular front is fixed. These bends, as with the ordinary half and three-quarter section, are designed to meet inlets connecting at various angles.

Bends should, if practicable, discharge into the main channel above the invert. If half-section channels are employed they can be deepened, say, 3 in., by the benching.

Drain chutes (Fig. 141) for connecting to the walls of inspection chamber and the main inlet and outlet pipes are serviceable, especially where deep channels are used.

Protection Guards or Gratings to Ventilating-pipe Openings

The open ends of pipes provided for ventilation need protection against obstruction and injury. A suitable requirement is that the end of every drain, soil, slop sink, and urinal ventilating pipe should be fitted ''with a suitable grating or cover having apertures of an aggregate area not less than the sectional area of the pipe for the purpose of preventing any obstruction in or injury to any

pipe or drain connected therewith by the introduction of any substance through any such opening'.[1] The Model by-laws[2] require every drain, soil, and slop sink ventilating pipe to be 'covered with a grating or other cover as a protection against injury or obstruction, which shall contain a sufficient number of apertures to admit of the free passage of air'.

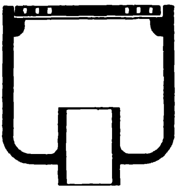


FIG. 142. Doulton's glazed stoneware air inlet.

Small ventilating pipes, such as 'puff' pipes, are sufficiently protected by fixing a few bars of strong copper wire in a slightly enlarged orifice. Pipes out of hand reach can be effectually protected by copper or galvanized-iron wire balloons.

Drain-ventilating openings distant from buildings and frequented places may be in the form of a pipe with plain grating. For fixing at the surface level the fitting given in Fig. 142 may be adopted. Often ground-level ventilators are seen in footways and other frequented places with the openings quite closed with earth and rubbish. Where this is likely the ventilator should be above the ground level with a protective grating.

For low-down positions close to buildings grated openings fitted with mica or aluminium valves are largely used, the theory being that such valves will act as fresh-air inlets and not as outlets for foul air. They seldom, however, act in the manner contemplated, frequently disseminate foul air, are often put out of order and rendered useless by misuse or neglect, and merely emphasize the desirability of providing the ventilating opening in a position where nuisance from the escape of foul air is unlikely.

[1] See footnote on p. 210.

[2] Urban, Series IV, 1925.

XIV

DRAIN, SOIL, WASTE, AND VENTILATING PIPES: MATERIALS

SEWAGE and surface water drains should be constructed of good sound pipes formed of cast-iron or glazed stoneware, and soil and soil-ventilating pipes of drawn lead, copper, cast-iron, or other equally suitable material. Drain-ventilating pipes and the waste and ventilating pipes attached to slop sinks and urinals should be constructed as soil pipes; and waste pipes from baths, bidets, sinks, and lavatory basins of lead, copper, iron, glazed stoneware, or other equally suitable material. For subsoil drains earthenware field or other suitable pipes are required.[1]

The Model by-laws[2] specify that all drains other than subsoil drains 'shall be formed of good sound pipes of glazed stoneware, or heavy cast iron', drain-ventilating pipes and soil pipes and waste pipes from slop sinks of 'heavy cast iron or lead'; or of other equally suitable material. The materials for waste pipes from bidets, urinals, sinks, baths, and lavatory basins are not stated. Subsoil drains must be of earthenware or other suitable pipes.

Lead Pipes and Traps

Manufacture. Years ago lead pipes and traps were commonly made by hand, cut lengths of sheet lead being turned on a mandrel and seamed either by burning or soldering, a practice now very occasionally adopted and generally held in disfavour when compared with solid drawn or seamless pipes made by forcing lead through a pipe machine, fitted with a core and die regulated to the size of the pipe undergoing manufacture, by means of a ram operated vertically by hydraulic or steam power with a pressure approximating to five tons per sq. in. Machine-

[1] See footnote on p. 210.

[2] Urban, Series IV, 1925.

made pipes are seamless and are made to various working lengths. Diameters of ⅛ in. to 1 in. are usually in coils of 60 ft., 1⅛ in. to 2 in. in coils of 36 ft., 2 in. to 2½ in. in 12 ft., and 3 in. to 6 in. in 10 ft. straight lengths. Solid-drawn bends and traps are made in a similar fashion with two rams working horizontally at varying regulated speeds, the ram working at the higher speed being utilized for forcing the lead through the part of the die forming the heel or outside of the bend.

Lead pipes used for soil, ventilating, and waste purposes in London[1] must be of *drawn* lead, a description not applied in the Model code.

Weight of pipes. The following are submitted as minimum weights:

TABLE NO. III, *giving minimum weights of lead soil and soil-ventilating and waste and waste-ventilating pipes.*[1]

	Weight per yard not less than :	
Diameter.	*Soil and soil ventilating pipes.*	*Waste and waste ventilating pipes.*
Inches	lb.	lb.
1	5	5
1¼	6¼	6¼
1½	7½	7½
1¾	8¾	8¾
2	10	10
2½	12½	12½
3	15	15
3½	19½	19½
4	22½	22½
4½	32	29
5	41	35½
6	57	50

The leading manufacturers are always prepared to make pipes on order to any desired weight, and generally stock the weights specified by the by-laws.

In Table No. X (Chapter XVI, p. 284) are given the thickness of walls and the weight of lead pipes having the nearest approximation to the minima quoted in Table No. III, and in addition, pipes of greater thickness and weight.

[1] See footnote on p. 210.

The weights given relate to *circular* pipes. Rectangular soil pipes may be obtained, the usual stock sizes being 6×4 in., 4×3 in., and $3\frac{1}{2} \times 3\frac{1}{2}$ in., of weights equal to either 7 or 8 lb. sheet lead; but these are not permitted under codes of by-laws where pipes used for the purpose indicated are required to be *circular*.

Cast-iron Pipes

Manufacture. Cast-iron soil, waste, ventilating, and drain pipes are made in the form of (1) straight spigot and socket pipes; (2) straight flange pipes; and (3) special castings. The casting is done horizontally, at an angle of 45°, or vertically, in dry sand moulds formed with turned iron patterns in faced and truly jointed boxes with a core, formed with a special loam or sand on perforated iron cylinders, through the centre of the mould.

The horizontal method is commonly followed in casting soil, waste, ventilating, rain-water and house-drainage pipes. For sewerage work, in which pipes of heavy weight are employed, vertical casting is generally stipulated.

Vertically cast pipes are the best, as they are of the same thickness throughout, free from air cavities and of an even texture, since the dross rises to the top of the mould and is cut off in a lathe, a sufficient length, which forms the casting head to ensure soundness, being allowed for this purpose. With the horizontal method of casting pipes of uneven thickness and texture are likely owing to sagging and movement of the core, the occurrence of air cavities, and the accumulation of dross at the top of the pipe. Pipes cast on an incline stand midway in quality between vertical and horizontal castings.

The British Engineering Standards Association[1] Specification provides that standard soil, waste, and ventilating pipes and fittings shall be made from remelted iron, the metal to be dark grey on fracture. They may be

[1] British Engineering Standards Association, Specifications Nos. 58 and 59. Pipes for conveying sewage must be cast vertically with socket downwards, Specification No. 78, 1917.

made pipes are seamless and are made to various working lengths. Diameters of ⅛ in. to 1 in. are usually in coils of 60 ft., 1⅛ in. to 2 in. in coils of 36 ft., 2 in. to 2½ in. in 12 ft., and 3 in. to 6 in. in 10 ft. straight lengths. Solid-drawn bends and traps are made in a similar fashion with two rams working horizontally at varying regulated speeds, the ram working at the higher speed being utilized for forcing the lead through the part of the die forming the heel or outside of the bend.

Lead pipes used for soil, ventilating, and waste purposes in London[1] must be of *drawn* lead, a description not applied in the Model code.

Weight of pipes. The following are submitted as minimum weights:

TABLE NO. III, *giving minimum weights of lead soil and soil-ventilating and waste and waste-ventilating pipes.*[1]

Diameter.	Weight per yard not less than : Soil and soil ventilating pipes.	Weight per yard not less than : Waste and waste ventilating pipes.
Inches	lb.	lb.
1	5	5
1¼	6¼	6¼
1½	7½	7½
1¾	8¾	8¾
2	10	10
2½	12½	12½
3	15	15
3½	19½	19½
4	22½	22½
4½	32	29
5	41	35½
6	57	50

The leading manufacturers are always prepared to make pipes on order to any desired weight, and generally stock the weights specified by the by-laws.

In Table No. X (Chapter XVI, p. 284) are given the thickness of walls and the weight of lead pipes having the nearest approximation to the minima quoted in Table No. III, and in addition, pipes of greater thickness and weight.

[1] See footnote on p. 210.

The weights given relate to *circular* pipes. Rectangular soil pipes may be obtained, the usual stock sizes being 6×4 in., 4×3 in., and $3\frac{1}{2} \times 3\frac{1}{2}$ in., of weights equal to either 7 or 8 lb. sheet lead; but these are not permitted under codes of by-laws where pipes used for the purpose indicated are required to be *circular*.

Cast-iron Pipes

Manufacture. Cast-iron soil, waste, ventilating, and drain pipes are made in the form of (1) straight spigot and socket pipes; (2) straight flange pipes; and (3) special castings. The casting is done horizontally, at an angle of 45°, or vertically, in dry sand moulds formed with turned iron patterns in faced and truly jointed boxes with a core, formed with a special loam or sand on perforated iron cylinders, through the centre of the mould.

The horizontal method is commonly followed in casting soil, waste, ventilating, rain-water and house-drainage pipes. For sewerage work, in which pipes of heavy weight are employed, vertical casting is generally stipulated.

Vertically cast pipes are the best, as they are of the same thickness throughout, free from air cavities and of an even texture, since the dross rises to the top of the mould and is cut off in a lathe, a sufficient length, which forms the casting head to ensure soundness, being allowed for this purpose. With the horizontal method of casting pipes of uneven thickness and texture are likely owing to sagging and movement of the core, the occurrence of air cavities, and the accumulation of dross at the top of the pipe. Pipes cast on an incline stand midway in quality between vertical and horizontal castings.

The British Engineering Standards Association[1] Specification provides that standard soil, waste, and ventilating pipes and fittings shall be made from remelted iron, the metal to be dark grey on fracture. They may be

[1] British Engineering Standards Association, Specifications Nos. 58 and 59. Pipes for conveying sewage must be cast vertically with socket downwards, Specification No. 78, 1917.

cast horizontally, shall be true, smooth, and cylindrical, their inner and outer surfaces being as nearly as may be concentric, in all respects sound and good castings, free from laps or other imperfections, neatly dressed and carefully fettled both inside and outside. Every pipe shall be tested for soundness by being struck all over with a light hand hammer, and every pipe and fitting have cast upon it in a legible manner a figure indicating the internal diameter and also Class Letters to indicate the purpose for which the pipe or fitting is made, together with the initials or trade mark of the manufacturer, e.g.:

4 | S.S. | X & Co.   4 | S.V. | X & Co.

These signs respectively indicate 'Standard Soil' and 'Standard Ventilating' pipes.

Weight, thickness, &c. The following are minimum requirements for cast-iron drain pipes, soil and soil-ventilating pipes (i.e. pipes used in connexion with water-closets, slop sinks, and urinals), drain-ventilating pipes, and waste and waste-ventilating pipes for sinks, baths, bidets, and lavatory basins:

TABLE NO. IV, *giving minimum weights, &c., of cast-iron drain, soil, waste, and ventilating pipes.*[1]

Diameter.	*Internal depth of socket not less than:*	*Caulking space not less than:*	*Thickness of metal for pipes and fittings not less than:*	*Weight per 9 ft. length (including socket and beaded spigot or flange) not less than:*
Inches.	Inches.	Inch.	Inch.	lb.
		Drain Pipes		
4	3	$\frac{5}{16}$	$\frac{3}{8}$	160
5	3	$\frac{3}{8}$	$\frac{3}{8}$	190
6	$3\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$	230
7	4	$\frac{3}{8}$	$\frac{7}{16}$	350
8	4	$\frac{3}{8}$	$\frac{7}{16}$	400
9	4	$\frac{3}{8}$	$\frac{7}{16}$	450

[1] See footnote on p. 210. The requirements of the Model by-laws are restricted to the description set out on p. 245.

Diameter.	Internal depth of socket not less than:	Caulking space not less than:	Thickness of metal for pipes and fittings not less than:	Weight per 9 ft. length (including socket and beaded spigot or flange) not less than:
Inches.	Inches.	Inch.	Inch.	lb.
		Soil and Soil-ventilating Pipes		*Weight per 6 ft. length*
1	—	—	—	—
1¼	—	—	—	—
1½	2¼	¼	$\frac{3}{16}$	22
1¾	—	—	—	—
2	2½	¼	$\frac{3}{16}$	24
2½	2¾	¼	$\frac{3}{16}$	30
3	2¾	¼	$\frac{13}{64}$	40
3½	3	¼	$\frac{13}{64}$	48
4	3	¼	$\frac{13}{64}$	54
4½	3¼	$\frac{5}{16}$	¼	66
5	3¼	$\frac{5}{16}$	¼	78
6	3½	$\frac{5}{16}$	¼	92
		Waste and Waste-ventilating Pipes		
1	—	—	—	—
1¼	—	—	—	—
1½	2¼	¼	$\frac{3}{16}$	22
1¾	—	—	—	—
2	2½	¼	$\frac{3}{16}$	24
2½	2¾	¼	$\frac{3}{16}$	30
3	2¾	¼	$\frac{3}{16}$	35
3½	3	¼	$\frac{3}{16}$	41
4	3	¼	$\frac{3}{16}$	47
4½	3¼	$\frac{5}{16}$	$\frac{3}{16}$	54
5	3¼	$\frac{5}{16}$	$\frac{3}{16}$	59
6	3½	$\frac{5}{16}$	$\frac{3}{16}$	71

Pipes for domestic drainage have not been standardized, but the B.E.S.S. for spigot and socket cast-iron soil, waste, and ventilating pipes is as shown in Table V, p. 250.

The leading manufacturers cast spigot and socket soil and drain pipes to meet by-law and the B.E.S.S. requirements above mentioned, also pipes of lesser and greater weight. Extra strong 3-, 4-, and 6-in. diameter soil pipes of $\frac{3}{8}$-in. metal can be obtained for use in hospitals, prisons, schools, and other places where special security is necessary.

Table No. XI (Chapter XVI, p. 289) gives weights, &c., of cast-iron drain, soil, waste, and ventilating pipes as

manufactured. Hitherto the weight and thickness of sink, bath, and lavatory waste and ventilating pipes have not been generally stipulated by by-law, hence the common practice has been to use either the soil-pipe weight or pipes of rain-water strength, according to the class of work.

TABLE NO. V, *giving the British Standard Specification*[1] *weights, &c., of cast-iron soil, waste, and ventilating pipes.*

Diameter.	*Internal depth of socket.*	*Caulking space.*	*Thickness of metal for* Pipes.	*Thickness of metal for* Sockets.	*Weight per 6 ft. length including socket and beaded spigot.*
Inches.	Inches.	Inch.	Inch.	Inch.	lb.
		Soil Pipes			
3½	3	¼	¼	5/16	55
4	3	¼	¼	5/16	63
4½	3¼	5/16	¼	5/16	70
5	3¼	5/16	¼	5/16	78
6	3½	5/16	¼	5/16	92
		Waste and Ventilating Pipes			
2	2½	¼	3/16	¼	24
2½	2¾	¼	3/16	¼	30
3	2¾	¼	3/16	¼	35
3½	3	¼	3/16	¼	41
4	3	¼	3/16	¼	47
4½	3¼	5/16	3/16	¼	54
5	3¼	5/16	3/16	¼	59
6	3½	5/16	3/16	¼	71

The thickness of the metal in fittings is often slightly less than that of the pipes. As the minimum requirement applies to both pipes and fittings the thickness should be identical. The varied weights given for drain pipes of equal diameter and thickness in the list quoted can only be explained on the ground that the thickness is *nominal* and not necessarily meticulously accurate. In all specifications therefore it is essential that either the *minimum* weight and thickness should be stipulated or reference made to compliance with a particular by-law standard.

[1] British Engineering Standards Association, Specifications Nos. 58 and 59.

Prevention of corrosion. Iron pipes subjected to the influence of either atmospheric or ground air are liable to corrode and a protective coating is consequently necessary. The interior surface of pipes actually used for the conveyance of sewage matter becomes coated with a thin film of sewage which in itself acts as a protective covering, but such protection does not obtain in the case of ventilating pipes, with the result on occasion that rusting takes place to such an extent as to bring about stoppage at the foot of the pipe, to counteract which rust pockets of the kind illustrated in Fig. 125, p. 234, are frequently fixed.

The exterior of soil, waste, and ventilating pipes fixed in exposed positions is oftentimes coated with metallic (lead or iron oxide) paint, but pipes in hidden situations do not receive such treatment, and in any case the method is inadequate against corrosion. Other methods include the coating of both the inside and outside surfaces with bitumen paint, a composition of pitch and tar, or hot coal-tar; but these can only be regarded as ineffectual and temporary expedients.

All cast-iron pipes used for drain and drain-ventilating pipes, soil and soil-ventilating pipes, and waste and waste-ventilating pipes should be coated on both the inside and the outside with Dr. Angus Smith's solution or be treated in some other equally suitable manner.[1] The Model code[2] stipulates that cast-iron drain pipes constructed on or in the ground shall be suitably protected against *external* corrosion; and the B.E.S.S. prescribes that all parts of the interior of soil, waste, and ventilating pipes and fittings shall be galvanized or coated with Dr. Angus Smith's solution or other approved composition as may be specified; with the provision that if vitreous enamel is used the coating shall be at least carried over the shoulder of the socket.

Effectual methods of preservation comprise: (1) coating with Dr. Angus Smith's solution; (2) oxidizing by the

[1] See footnote on p. 210.

[2] Urban, Series IV, 1925.

Bower-Barff process; (3) galvanizing; (4) glass or vitreous enamelling; and (5) porcelain enamelling.

Dr. Angus Smith's solution is the coating most commonly adopted. The solution is acid-resisting and, properly applied, will prevent the corrosion of cast- and wrought-iron pipes.

The process is varied by different authorities and manufacturers. The B.E.S.S. provides that before the pipe shall have become affected by rust 'it shall be heated to a suitable temperature not exceeding 250° F. and perfectly coated, in the most approved manner, by being dipped, except in the case of pipes which are to be only partially coated, in a bath of approved composition maintained at a temperature of not less than 300°, nor more than 330° F. according to Dr. Angus Smith's process. When the pipe is removed from the bath it shall be properly drained, and the coating must fume freely and set hard within an hour. If the coating does not so fume and set, the pipe shall be recoated '.[1]

Some manufacturers omit, on the grounds of expense, the heating of the pipes prior to dipping, but this process is not effective and should not be accepted.

The Bower-Barff processes protect iron and steel from oxidization by a coating of black magnetic oxide. The original process consists of subjecting the pipes for a period of from six to twelve hours to the action of superheated steam in a muffle or kiln having a temperature of 900° to 1,200° F. The hot metal decomposes the steam and combines with some of the oxygen to form a coating of magnetic oxide of iron. A variation of the process is to subject the heated pipes first to the action of producer gas burnt with a slight excess of air, and then to producer gas alone, the result being the formation of magnetic oxide on the pipe surface. The process is more expensive than coating with bitumen or galvanizing, but is most effective. Pipes so treated do not easily 'spread' rust on being cut.

[1] British Engineering Standards Association, Specification No. 78, 1917.

Galvanizing affords a satisfactory protective coating provided it is not exposed to acid fumes or atmospheres which quickly corrode zinc. The process is more costly than bituminizing. In it's application the pipes are cleaned by steeping for about eight hours in water containing 1 per cent. of sulphuric acid, then scoured with sand and washed in clean water. The metal is then immersed in a flux of chloride of zinc and afterwards plunged in a bath of molten zinc.

Glass or vitreous enamelling is employed for the coating of the interior of pipes. In the application of the process the metal is cleaned, coated with a composition of lead oxide, silica, tin oxide, china clay, and borax and placed in a kiln having a temperature sufficient to fuse the composition and convert it into a glass enamel adhering to the surface of the metal. It is an excellent protective medium.

Porcelain enamel is used to a limited extent for coating the outside of waste pipes, but is seldom applied to the interior surface, the practice being to coat the latter either with a bituminous solution or glass enamel. The method improves both the appearance and the smoothness of the pipe.

The great weakness of all these protective materials is the liability of being chipped, scaled, or otherwise damaged by accident or rough usage, and in cutting and fitting the pipes, causing exposure of the bare metal with likelihood of corrosion. Where cutting is necessary pipes should first be fitted and then coated or treated, a practice, however, that substantially increases the cost of the work.

Wrought-iron Pipes

Pipes made of wrought-iron are occasionally used as soil pipes, and more often as sink, bath, and lavatory basin waste pipes. Where used, their strength and coating must be satisfactory, as the standard is that they shall be equally suitable to cast-iron pipes. They should be of water strength made from best quality puddled iron, and lap

welded. The metal oxidizes quickly in water and in air charged with acids or moisture, and its 'life' is only about half that of cast-iron. The metal can be protected against corrosion by the methods suggested for cast-iron pipes, the most usual treatment being galvanizing.

Mild-steel pipes are also used, but are inferior to wrought-iron as they are more liable to corrosion, particularly in exposed positions or where buried underground.

The weight and thickness of standard wrought-iron pipes of water strength are detailed in Table No. XII (Chapter XVI, p. 290).

Copper Pipes[1]

In good-class work where appearance is of importance polished copper pipes are often used for above-floor waste pipes of lavatory basins. Their neatness, smoothness, strength, and non-corrosiveness may be suggested as reasons for more general use both for waste and waste-ventilating pipes and soil and soil-ventilating pipes. While dearer in first cost than cast-iron they would probably show a saving in ultimate cost owing to a longer 'life'. Compared with lead, a saving in first cost can, in many installations, be shown, while the life of the metal is at least as long as lead with less likelihood of damage and consequential cost in maintenance.

Of the marketable forms—'annealed', 'medium', and 'hard wrought'—either annealed or medium can be employed, the former being preferable for safety's sake as it meets cases where, for jointing, pipe ends are annealed—an unnecessary proceeding and one which can be avoided by specifying copper of medium temper. All pipes should be solid drawn.

Low-pressure copper pipes may be classified as (1) pipes with screwed joints, and (2) pipes with compression joints. The B.E.S.S.[2] provides that such pipes must (*a*) contain

[1] The expression 'tubes' is generally used, but to secure uniformity 'pipes' is adhered to in these references.

[2] British Engineering Standards Association, Specification No. 61, 1913.

not less than 99·25 per cent. of copper and 0·25 to 0·45 per cent. of arsenic; (*b*) be clean, smooth, and free from surface defects or longitudinal grooving, internally and externally, and the ends clean and square; and (*c*), for working pressures up to 50 lb. per sq. in., comply with the weight and thickness set out in Table No. XIII (A). (Chapter XVI, p. 291.)

The Model by-laws[1] issued by the Ministry of Health require compliance with the B.E.S.S., subject to the proviso 'that in the case of any pipe with suitable and efficient joints, not being screwed joints, the thickness of the pipe may be *three gauges* lighter than the British Engineering Standards Specification'. These gauges are set out in (B), Table No. XIII (Chapter XVI, p. 291).

Pipes of the weights and thicknesses referred to are designed for water services. For use as soil and soil-ventilating and waste and waste-ventilating pipes lesser weights and thicknesses are sufficient. If regard is had to the relative strengths of lead and copper pipes as set out in Tables Nos. X and XIII (Chapter XVI, pp. 284 and 291), and to the suggested minimum requirements for the former (Table No III, p. 246), the weights and thicknesses given in (C) Table No. XIII (Chapter XVI, p. 291) may be accepted as meeting all normal needs.

Glazed Stoneware Pipes

Manufacture. Stoneware pipes are made from the plastic clays of the Lias formation and certain hard fire-clays from the Coal-measures of the Midlands and other mining areas. The description 'stoneware' is not, however, specifically confined to the use of a particular clay, for pipes made from any kind of highly vitrifiable clay are described as such. Scotch pipes and enamelled channels are invariably made from fireclay. The manufacture of stoneware pipes is on the following lines.

[1] *Water Pipes and Fittings*, 1926.

The clay, if in a state too wet for grinding, is either air-dried or dried on hot metal plates; ground in a mill and mixed (in the case of a rich clay—such as Devon or Dorset) with a proportion of silver sand and ground-up broken stoneware pipes in fine powder form to prevent undue shrinkage: and mixed with water in a mixing-mill and pug-mill to produce a plastic consistency. It is then placed in a press, operated either by a steam ram or by a rotating screw, and forced through a die which forms first the socket and then the barrel of the pipe.

The pipe is next lifted off on to a revolving table where the ends are trimmed and the inside of socket grooved; or in the case of 4-in. pipes and under, placed on the mandrel of a lathe where the trimming and grooving takes place, about 1 in. of unwanted material being left on the spigot end so as to allow for damage during drying. They are then placed in a vertical position in heated drying rooms until dry enough to be ready for the kiln.

The kiln is usually circular on plan, but in some instances a rectangular kiln is used. It is partly divided into bays by walls about 8 ft. in height to prevent movement or swaying of the pipes during firing, fitted with a floor in grating form with flue leading to a chimney shaft and a domed top having a series of small openings, and furnished with a number of small furnaces fed from the outside of the kiln.

The kiln is filled from floor to top with pipes and fittings, the means of access are roughly bricked up, and the openings in top closed. Coal is used for firing, and the time occupied in the process varies with the size of the pipes. Kilns containing small pipes are brought up to the maximum temperature of 1,250° C. in about four days. During the firing common salt (chloride of sodium) is thrown into the furnaces, is volatilized by the heat, and the vapour drawn through the pipes and fittings. The sodium combines with the silica in the clay to form silicate of soda, which is the surface coating of glass known as

salt-glaze. After firing, the kiln is gradually cooled by reopening the sealed means of access. Considerable shrinkage takes place during firing. For instance, a 9-in. pipe is made $9\frac{3}{4}$ in. internal diameter and about 2 ft. $8\frac{1}{2}$ in. long so as to provide a finished article 9 in. in internal diameter by an overall length of 2 ft. 6 in.

Traps and other fittings are hand moulded in plaster-of-Paris moulds (halves), joined up, trimmed and burnished. Junction pipes are connected by hand. Large street gullies are made as pipe lengths, the bottoms and outgoes being placed on and the rims made by hand. These fittings are then air-dried and fired in the same way as plain pipes. Pipes thus made in the best manner and of suitable materials are highly vitrified throughout, strong, durable, practically impenetrable to moisture and acid-resisting.

Earthenware Pipes

These pipes are made from the clay used for tiles and bricks. They cannot be highly vitrified or properly salt-glazed, and being weak and porous are not accepted for sewage drains, but can usefully be employed for subsoil drains, where their porosity is immaterial.

Concrete Pipes

Of late years these have been recognized as suitable for surface-water drains and sewers, but have not been adopted to an appreciable extent, or made in suitable sizes, for domestic drainage.

Thickness, &c., of Glazed Stoneware Pipes

Stoneware pipes should be of first quality properly glazed, and the thickness of the pipes and fittings, the internal depth of the sockets, and the jointing space in conformity with Tables VI and VII, p. 259.

The width of shoulder of socket must exceed the mean

thickness [1] of the barrel by not less than the dimensions stated in Column D of Table No. VII.

The B.E.S.S. comprises pipes of two standards, (1) British Standard Pipes, subject in every respect to the requirements of the specification, but of which only 5 per cent. of the pipes ordered are submitted to the hydraulic test mentioned in Chapter XVI, p. 292; and (2) British Standard Tested Pipes, all of which comply in every respect with the full requirements of the specification.

Pipes purporting to have been made in conformity with the specification must be marked—

X & Co.

for British Standard Pipes, and

X & Co.
TESTED

for British Standard Tested Pipes.

Unsuitable Pipes

The limitation of materials to those specified, or materials equally suitable, effectively rules out the use of unsatisfactory forms and substances. Thus, for soil- and waste-pipe purposes zinc, sheet iron and steel, cast-iron of rain-water strength, and stoneware cannot properly be accepted on account of fragility, difficulty of ensuring sound joints, or fixing; neither can barrel drains of brick or stone be approved because of the large fouling surface, non-cleansing shape, and the impossibility of being constructed and maintained in a water- and gas-tight condition; nor unglazed earthenware pipes owing to softness, porosity, and lack of facilities for jointing.

[1] The mean thickness of the barrel (or socket) of any individual pipe shall be ascertained by adding the measured least thickness to the greatest thickness and dividing the sum by two.

TABLE NO. VI, *giving minimum thickness, &c., of glazed stone-ware drain-pipes.*[1]

Internal diameter:	*Internal depth of socket not less than:*	*Jointing space not less than:*	*Thicknesss of pipe and fittings not less than:*
Inches.	Inches.	Inch.	Inch.
4	2	$\frac{3}{8}$	$\frac{1}{2}$
5	$2\frac{1}{4}$	$\frac{7}{16}$	$\frac{9}{16}$
6	$2\frac{1}{4}$	$\frac{7}{16}$	$\frac{5}{8}$
7	$2\frac{1}{4}$	$\frac{7}{16}$	$\frac{11}{16}$
8	$2\frac{1}{2}$	$\frac{1}{2}$	$\frac{11}{16}$
9	$2\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{4}$

The B.E.S.S. is as follows:[2]

TABLE NO. VII, *giving the British Standard Specification thickness, &c., of Salt-Glazed Ware Pipes.*

Internal diameter of pipe.	*Minimum mean thickness of barrel.*[3] A	*Minimum mean thickness of socket.*[3] B	*Minimum internal depth of socket.* C	*Minimum jointing space.* D	*Length of grooving on spigot.* E	*Minimum depth of grooving.* F
in.	in.	in.	in.	in.	in.	in.
3	$\frac{7}{16}$	$\frac{7}{16}$	2	$\frac{5}{16}$	3	$\frac{1}{16}$
4	$\frac{1}{2}$	$\frac{1}{2}$	2	$\frac{3}{8}$	3	$\frac{1}{16}$
5	$\frac{9}{16}$	$\frac{9}{16}$	$2\frac{1}{4}$	$\frac{7}{16}$	$3\frac{1}{8}$	$\frac{1}{16}$
6	$\frac{5}{8}$	$\frac{5}{8}$	$2\frac{1}{4}$	$\frac{7}{16}$	$3\frac{3}{8}$	$\frac{1}{16}$
7	$\frac{11}{16}$	$\frac{11}{16}$	$2\frac{1}{4}$	$\frac{7}{16}$	$3\frac{5}{8}$	$\frac{1}{16}$
8	$\frac{11}{16}$	$\frac{11}{16}$	$2\frac{1}{2}$	$\frac{1}{2}$	$3\frac{3}{4}$	$\frac{1}{16}$
9	$\frac{3}{4}$	$\frac{3}{4}$	$2\frac{1}{2}$	$\frac{1}{2}$	$3\frac{3}{4}$	$\frac{1}{16}$

[1] See footnote on p. 210.
[2] British Engineering Standards Association, Specification No. 65, 1914.
[3] See footnote 1, p. 258.

XV

DRAIN, SOIL, WASTE, AND VENTILATING PIPES: JOINTING AND FIXING

THE JOINTING OF PIPES

DRAIN, soil, and waste pipes used for conveying excretal matters and the ventilating pipes connected therewith require a form of joint both water- and gas-tight for the reason that such pipes are directly connected to the drain and any defect means the dissemination of drain air.

Pipes conveying waste matters from sinks, baths, and lavatory basins and the connected ventilating pipes need equally sound joints when fixed within buildings, for although these pipes discharge into or over gully traps the interior becomes coated with greasy matters giving off offensive odours; but such waste pipes, if fixed in exterior positions and distant from windows and other openings into any building, need not be so meticulously guarded against the escape of air therefrom, though a sound water- and gas-tight joint is always best as it limits the points of discharge of foul air to the waste outlet at the foot and the open top provided for ventilation.

Suitable forms of jointing are[1]:

Lead pipes. Fused or burned, or wiped plumbers' joints.

Copper pipes. Compressed joints made with union nut or flanged couplings, or other equally suitable joints.

Cast-iron socketed pipes. A gasket of hemp or yarn and metallic lead properly caulked.

Cast-iron flanged joints. Securely bolted together with some suitable insertion.

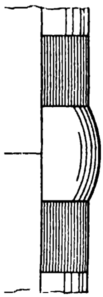
Stoneware pipes and pipes of material other than metal. Socket joints properly put together with a gasket of hemp or yarn and cement; or other equally suitable materials.

These requirements apply to drain pipes, soil pipes,

[1] See footnote on p. 210.

waste pipes for fitments conveying faecal matter, waste pipes from sinks, baths, and lavatory basins, and to the respective ventilating pipes. Joints made in an equally suitable and efficient manner may be accepted.

For drains the Model[1] code stipulates 'suitable water-tight joints', but is silent as to the mode of construction, and omits any reference to the jointing of pipes used for the other purposes mentioned above.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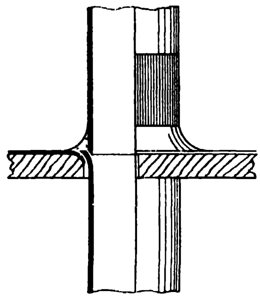
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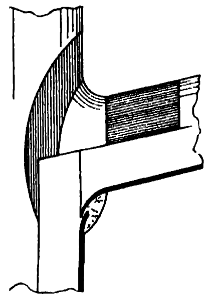
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FIG. 143. Wiped joint connecting straight lengths of lead pipe.
FIG. 144. Wiped flange, block, or taft joint connecting lead pipes.
FIG. 145. Wiped branch joint connecting lead pipes.

Lead Pipes

Wiped plumbers' joints[2] are made by hand-wiping the ends of the pipes to be joined with plumbers' solder, as distinct from 'blown' joints and those made with a copper bit. Figs. 143, 144, and 145 show a round wiped joint between straight lengths of piping, a flange, block, or taft joint, and a branch joint. Flange joints are useful where the pipes are so recessed that a fixing block can be utilized and for joints made at the point where pipes are passed through a floor. Pipes supported by brackets, as in Fig. 179, are also connected in this manner.

Fused or burned joints are made by fusing the slightly socketed pipe ends with the aid of an oxy-hydrogen flame. To thicken and strengthen the joint a strip of lead is commonly fused with the pipe ends.

[1] Urban, Series IV, 1925.
[2] The 'Amalgaline' method of jointing is accepted by some authorities.

Lead pipes with wiped or fused joints are not satisfactory for discharges of hot water from baths, bidets, sinks, and lavatory basins, for the range of expansion and contraction is such as to bring about twisting, or buckling and breaking of the pipe. For external positions where not prohibited by by-law an ordinary type expansion joint of the

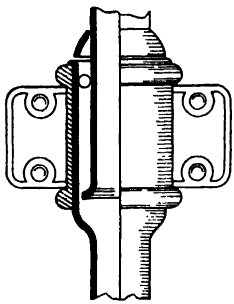


FIG. 146. Expansion joint for lead pipes.

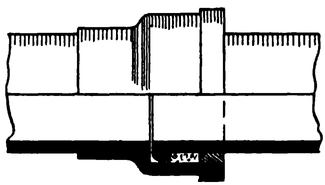


FIG. 147. Spigot and socket joint for cast-iron drain pipe caulked with 'Lead wool'.

kind illustrated by Fig. 146 can be used; or a 'Century' Patent Lead Socket soldered on, in which the cast-lead socket is strengthened by a tinned copper lining embedded in the centre of the body and tacks, with a tinned gun-metal screw-gland stuffing box rivcted to the copper body and tacks. For internal positions cast-iron pipes with caulked joints should be employed.

For the reason just given, waste pipes of lead with wiped or fused joints are not suited for use with slop sinks and hospital fitments designed for cleansing bed-pans and urine bottles, if hot water is the cleansing agent. Where such waste pipes have to be constructed as soil pipes, expansion joints of the kind just referred to would not be allowed. The better arrangement, in the circumstances, is to use cast-iron pipes with lead-caulked joints both for internal and external positions.

Cast-iron Pipes

Caulked joints for cast-iron pipes are made with metallic lead with or without a gasket of hemp or yarn (Fig. 147).

Molten lead is prescribed by some by-laws and is still largely used.

The usual method of making run joints is to insert a gasket of spun yarn into the annular space between the socket and spigot and then pour molten lead until the space is full, mastic clay being placed to form a ring to contain the molten metal when the joint is made in a horizontal position. On cooling, the lead shrinks away from

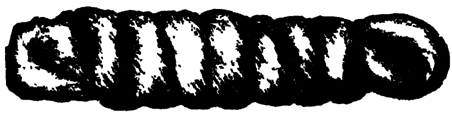


FIG. 148. Skein of 'Lead wool' for caulking cast-iron pipes.

the socket and it is necessary to caulk it so as to fill the space tightly. A weakness of this form is that the whole of the lead is not compressed as the caulking only affects the lead for a short distance down in the socket. Further, the joint cannot be made in the presence of water or moisture, for unless the pipes are perfectly dry the moisture will be converted by the hot metal into steam and blow out the lead, with the possibility of an accident to the workman.

'Ribbonite' lead and 'lead wool' are largely superseding molten lead. 'Ribbonite' consists of cast lead in a shredded form made into a rope which is placed loose in the joint and thoroughly caulked down in successive layers until the socket is full. 'Lead wool' is in the form of fine threads of pure lead cut by machinery so that it will easily weld together when hammered, the threads being rolled up as a rope in diameters of $\frac{5}{16}$, $\frac{3}{8}$, $\frac{1}{2}$, and $\frac{5}{8}$ in. as suited for pipes of 4- to 12-in. diameters (Fig. 148). As with 'Ribbonite', the joint is made by inserting a gasket of spun yarn and gradually filling in (caulking as the filling in proceeds) with the 'wool'.

The use of lead in the forms described is more economical than the run joint inasmuch as a smaller quantity of metal is required. A stronger joint is also obtained as the

lead is caulked throughout and not merely on the surface, and another estimable advantage is that the work can be done in the presence of water. Neither material comes within the category or description of 'molten' lead, but their use is generally allowed even where the by-laws prescribe the latter.

Table No. VIII gives the manufacturers' quantities of 'lead wool' and spun yarn necessary, and may be compared with the average weights of lead used in the ordinary run joint as given in Table No. IX.

TABLE No. VIII, *giving the amount of 'lead wool' and spun yarn required for caulking the joints of the cast-iron pipes given in Table No. IV, on p. 248.*

Diameter of pipe in inches.	*Lead wool*			*Spun yarn*			
	Depth in inches.	*Weight lb.*	*oz.*	*Skeins.*	*Depth in inches.*	*Weight lb.*	*oz.*
			Drain Pipes				
4	1	2	2	2	2		6½
5	1	3	3	3	2		9
6	1¼	4	4	4	2¼		12
7	1⅜	5	5	5	2⅝	1	0
8	1⅜	6	6	6	2⅝	1	2
9	1⅜	6	14	6½	2⅝	1	4
			Soil and Soil-ventilating Pipes				
1½	¾		8½	½	1½		1½
2	⅞		12	¾	1⅝		2
2½	1	1	1	1	1¾		2½
3	1	1	5	1¼	1¾		3
3½	1	1	5	1¼	2		4
4	1	1	10	1½	2		5
4½	1⅛	2	6	2¼	2⅛		6½
5	1⅛	2	10	2½	2⅛		8
6	1¼	3	8	3¼	2¼		10
			Waste and Waste-ventilating Pipes				
1½	¾		8½	½	1½		1½
2	⅞		12	¾	1⅝		2
2½	1	1	1	1	1¾		2½
3	1	1	5	1¼	1¾		3
3½	1	1	5	1¼	2		4
4	1	1	10	1½	2		5
4½	1⅛	2	6	2¼	2⅛		6½
5	1⅛	2	10	2½	2⅛		8
6	1¼	3	8	3¼	2¼		10

TABLE No. IX, *giving the average weight of lead used for caulking the joints of cast-iron pipes with 'molten' or 'run' lead.*

Diameter of pipe in inches.	*Average weight of lead used.*	
	lb.	oz.
$1\frac{1}{2}$	1	3
2	1	12
3	2	5
4	4	0
5	5	0
6	6	8
7	7	12
8	8	3
9	10	6

The design of the socket is of importance in connexion with the strength of the joint and should conform to the minimum requirements of the B.E.S.S. as in Fig. 149. A socket of excellent pattern is the 'Pam' patent corrugated socket made by Messrs. Burn Bros. (London), Ltd., for which it is claimed that the corrugations hold the lead tightly in position and prevent the outward movement sometimes seen with plain sockets, resulting from diverse expansion and contraction of the metals during temperature variations.

Caulked joints have occasionally proved unsatisfactory where a large quantity of hot water has been passed through the drain, the varying and extensive expansion and contraction forcing the lead out of the sockets. To overcome this difficulty an expansion joint with asbestos rings or other jointing material is sometimes suggested in a length of drain. Such a joint is of no use where the pipe is embedded in concrete, and is not free from objection for a drain situated under an occupied building, as reliance cannot be placed upon its air-tightness.

If pipes with 'Pam' or similar sockets are employed with 'ribbonite' or 'lead wool' as the jointing material, a movement of the lead sufficient to cause a defect is far less likely to occur than if the joints are 'run' with lead.

Turned and bored joints are spigot and socket joints, but

having half of the spigot and socket turned and bored in a lathe so that they fit closely, these surfaces being coated either with litharge or Portland cement before the spigot is driven home into the socket with the aid of a heavy wood maul or mallet. The joints are watertight if carefully made, but to make them permanently secure they are often

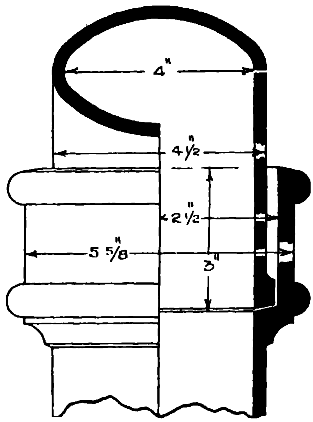


FIG. 149. Cast-iron pipe spigot and socket (British Standard Specification).

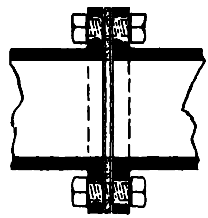


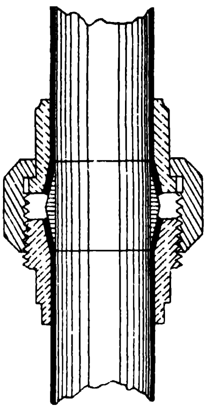
FIG. 150. Flange joint of cast-iron drain pipe with felt washer.

caulked as before described. For drainage work no real advantage is obtained by their use where caulking with metallic lead is compulsory; on the other hand they merely increase the cost of the work.

Flange-jointed pipes are not so frequently employed in soil pipe or drainage work as the spigot and socket pattern. The abutting ends of the flanges are sometimes faced in a lathe. The nuts and bolts should be of galvanized iron, or, better still, of gunmetal. Various packing materials or insertion are in use—sheet lead, asbestos, cardboard, and greased felt, the last-mentioned being the most suitable for pipes conveying sewage matter. Fig. 150 illustrates a joint in section.

Rust cement is used for joining socketed pipes. A sound joint can be assured, but as it necessitates the use of

uncoated iron pipes the method would not be permissible where the latter are prescribed; neither would these joints be accepted where caulked joints made with metallic lead are specified. Rust cement can be made by mixing clean and fine cast-iron borings with sal ammoniac or flour of sulphur, or both, the borings being first damped. The



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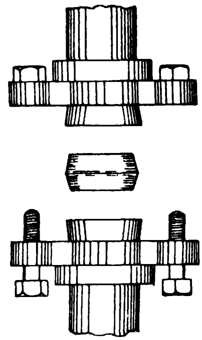

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FIG. 151. Section of 'Kongrip' cone compression joint for light copper pipes up to 2½ in. in diameter.

FIG. 152. Two-bolt 'Kongrip' flange compression joint for light copper pipes up to 2½ in. in diameter.

proportions are 4 oz. of sal ammoniac to 56 lb. of borings. This makes a slow-setting cement. If a quick-setting cement is needed sulphur should be used instead of sal ammoniac.

Portland cement is made use of for jointing iron pipes, but the joints thus made are subject to cracking.

Red and white lead are used in combination in a mastic form, but the material is unsatisfactory, as it hardens, becomes very brittle, and cracks. The expansion and contraction of the iron pipes also has a tendency to squeeze the composition out of the socket.

Wrought-iron Pipes

These are joined by screwed couplings or flanges. The

filling substance for couplings is usually a red-lead paint, graphite, or other similar cement or compound. Asbestos or felt washers are used for flange joints. The flange type

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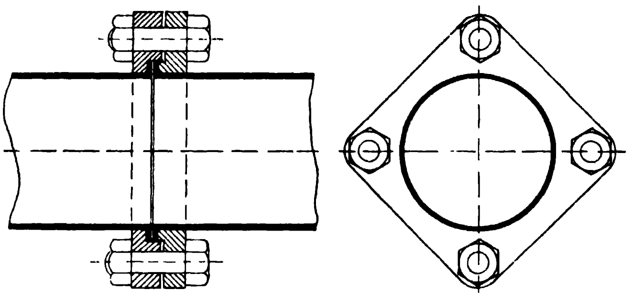

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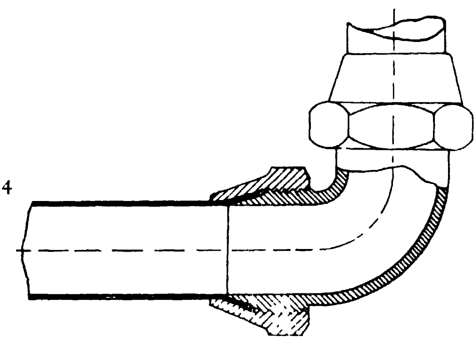

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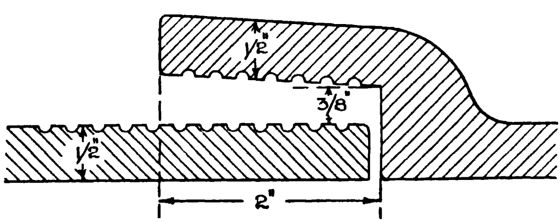


FIG. 153. Four-bolt flange joint for light copper pipes exceeding 2½ in. in diameter.

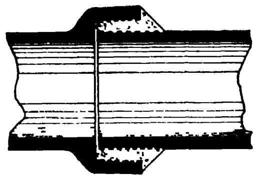
FIG. 154. A bend or elbow connexion for light copper pipes.

FIG. 155. British Standard Specification spigot and socket joint for 4-in. internal diameter salt-glazed ware pipe.

is the best, for if carefully fitted the screwed ends meet so as to preserve the continuity of the pipe. Junctions with screwed spigots are obtainable for branch connexions.

Copper Pipes

All joint fittings should be of high quality brass without any reduction in bore. For pipes of the thickness given in (A), Table No. XIII (Chapter XVI, p. 291), screwed joints should be used; for those in (B) and (C), compressed joints. If flanged, the pipe should not be turned over so sharp as to strain the metal. Of the many compressed joints in use Figs. 151 and 152 illustrate good forms for pipes up to $2\frac{1}{2}$ in. internal diameter; Fig. 153 a joint for larger diameter pipes; and Fig. 154 the connexion of a pipe to a fitting. For junctions, brass unions can be used in the form of curved tees. Bends are best made in the pipe with the aid of a bending machine.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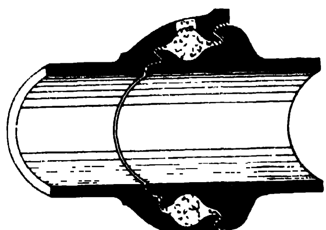
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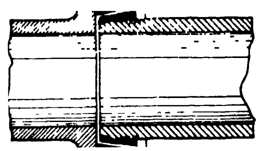
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FIG. 156. Plain spigot and socket jointed with cement.

FIG. 157. The 'Yarrow' patent joint as applied to salt-glazed ware pipes.

FIG. 158. Original type of 'Stanford' joint.

Glazed Stoneware Pipes

In London[1] it is provided that if a drain be constructed of stoneware pipes or pipes of material other than metal, it shall be jointed with socket joints properly put together with cement[2] or other equally suitable material. The depth of socket and the annular space for the jointing material are as set out in Table No. VI, p. 259. Fig. 155 illustrates a B.E.S.S. joint. Varied types of joints are used

[1] See footnote on p. 210.

[2] That is 'Portland cement of the best quality'.

to comply with the requirements, but they are all spigot and socket and fall into one of three classes: (1) joints made with Portland cement; (2) joints made with bitumen; and (3) joints made with Portland cement and bitumen.

Of joints made with Portland cement alone, the plainest type is of the kind shown by Fig. 156. Fig. 157 illustrates the 'Yarrow' patent joint, in which the jointing material is cement grout poured into the sealing chamber after the pipes have been placed in position with clay or plastic cement against the abutting edges. The 'Yarrow' joint is applied to stoneware, concrete, cast-iron and steel pipes variously used for sewers, drains, water and steam mains, and soil, waste, ventilating, and rain-water pipes.

Fig. 158 shows a joint made solely with bitumen. It is the original form of 'Stanford' joint and consists of rings of bitumen cast on the spigot and within the socket. In joining, the rings are smeared with grease and mechanically fit one into the other.

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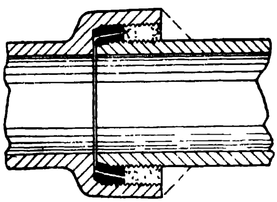

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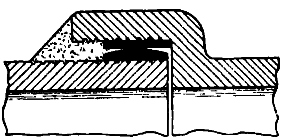

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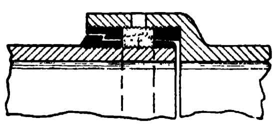


FIG. 159. Deep-socket type of 'Stanford' joint.

FIG. 160. The 'Hassall' single-lined joint.

FIG. 161. The 'Hassall' double-lined joint.

Composite joints (i.e. joints made with both bitumen and cement) of various kinds are illustrated by Figs. 159 to 161. Fig. 159 is a section of the improved 'Stanford' joint applied to a socket of sufficient depth to allow for an exterior fillet of cement. Fig. 160 represents a single-lined 'Hassall' joint with bitumen rings and cement fillet; and Fig. 161 a double-lined joint having separate rings of bitumen with cement grouting between.

Another example is Doulton's 'grouted composite'

double-seal joint in which both the spigot and socket are of special design with a flange on the former. Bitumen rings are provided and a canvas band attached to the socket and the flange on the spigot by binding wires, the space thus enclosed being filled with cement grout. The province of the canvas, which is porous, is to act as a filter cloth, permitting the escape of air and superfluous water and retaining the solid particles of cement.

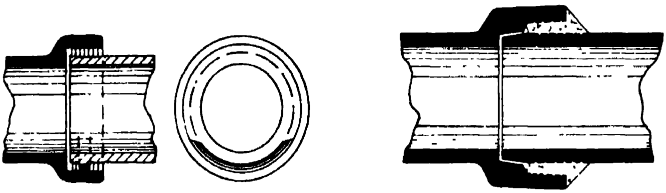
Portland cement joints (Fig. 156) give good results if properly made with cement of the best quality. With neat cement there is a risk of cracking by shrinkage on setting. To reduce this risk a small quantity of washed sand is often added to the cement, but the sand has a tendency to make the composition more porous. If 'Super Cement' is used or a waterproofing substance added (for instance, 'Pudlo') the mastic can then be made of equal parts of washed sand and cement. The use of 'killed' cement should always be avoided. On completion of the joint a wad or other appliance should be passed through the pipes for the purpose of seeing that the interior is quite free of cement.

Bitumen joints of the kind shown by Fig. 158 can be passed as watertight when newly made, but are always liable to become leaky owing to softening of the bitumen, a condition often arising where hot water is passed through the pipes. Unquestionably bitumen joints are an improvement upon the plain cement type if combined with cement in mastic or grout form, as variously illustrated by Figs. 159 to 161. The bitumen should be acid and alkaline proof.

Grouted or double-lined joints are specially useful where the pipes are to be laid in waterlogged ground or where there is a flow of water through the drain being laid, for the bitumen rings seal the pipes and permit the application of the cement.

Concrete pipes are jointed with cement in like manner to plain stoneware pipes.

Concentricity of the pipes is essential. In laying plain pipes (Fig. 156) a risk is entailed of the invert of the spigot end sinking below the pipe invert adjoining the socket and thus forming a projection in the pipe which interferes with the free passage of solid matters and tends to produce a stoppage. Concentricity is secured by some



162 163

FIG. 162. Doulton's 'Level-invert' joint.
FIG. 163. Doulton's 'Self-centering' joint.

workmen with a packing substance or a small quantity of cement mastic placed in the lower half of the socket and allowed to set before proceeding to make the joint, but this method interferes with the homogeneity of the latter.

Accurate concentricity is obtained by all bitumen-ringed pipes. To secure a continuous line of invert various special devices are now incorporated in plain-jointed stoneware pipes. Of these, Figs. 162 and 163 respectively show (*a*) Doulton's 'level-invert' joint having a socket with rest-piece extending about one-third round the socket, and (*b*) the same manufacturer's 'self-centering' joint, in which the inner end of the socket is contracted in diameter and tapered to correspond with the outer end of the spigot, plastic cement being used between the tapered portions for making a preliminary joint prior to the completion of the joint with Portland cement. Another form is Knowles's 'free-flow' pipe.

Connexion of Soil and Soil-ventilating Pipes, Traps, and Drains

The best modern practice may be summarized as follows: [1]

The connexion of the trap of any water-closet with a soil pipe, ventilating pipe, or drain, or the connexion of any soil pipe or ventilating pipe with a drain, shall be made in the manner and with the jointing materials hereinafter provided or otherwise in an equally suitable and efficient manner, and with equally suitable materials, and so as to preserve the continuity of the trap, pipe, or drain without obstruction:

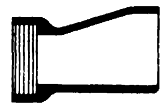


FIG. 164. Glazed stoneware level-invert taper pipes.

(*a*) The connexion of a lead trap with a lead pipe shall be by a fused or burned, or wiped plumber's joint.

(*b*) The connexion of a lead pipe or trap with a copper pipe or trap shall be by a wiped plumber's joint.

(*c*) The connexion of a lead pipe or trap with an iron pipe, trap, or drain, shall be by means of a thimble or flanged ferrule of copper, brass, or other suitable alloy connected with the lead pipe or trap by a wiped plumber's joint, and with the iron pipe, trap, or drain by a joint made with gasket of hemp or yarn and metallic lead properly caulked.

(*d*) The connexion of a lead pipe or trap with a stoneware pipe, trap, or drain, shall be by means of a thimble or ferrule as described in (*c*) connected with the lead pipe or trap by a wiped plumber's joint and with the stoneware pipe, trap, or drain by a joint made with a gasket of hemp or yarn and cement.

(*e*) The connexion of a copper trap with a copper pipe shall be by means of a union nut or flanged coupling.

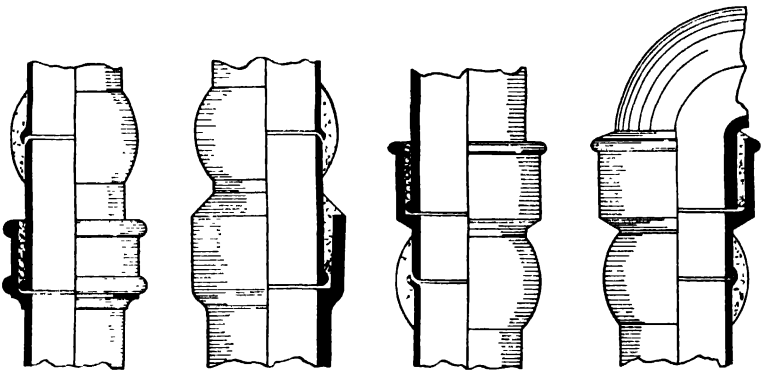
(*f*) The connexion of a copper pipe or trap with an iron pipe, trap, or drain shall be by means of a thimble or flanged ferrule of copper, brass, or other suitable alloy connected with the copper pipe or trap by a union nut or flanged coupling, and with the iron pipe, trap, or drain by a joint made with a gasket of hemp or yarn and metallic lead properly caulked.

(*g*) The connexion of a copper pipe or trap with a stoneware pipe, trap, or drain, shall be by means of a thimble or ferrule as

[1] See footnote on p. 210.

described in (*f*) connected with the copper pipe or trap by union nut or flanged coupling and with the stoneware pipe, trap, or drain by a joint made with a gasket of hemp or yarn and cement.

(*h*) The connexion of an iron pipe or drain with an iron trap shall be by a joint made with a gasket of hemp or yarn and metallic lead properly caulked.



165 166 167 168

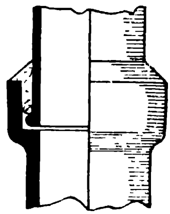
Fig. 165. Connexion of lead pipe to iron pipe by ferrule, wiped and lead-caulked joints. *Fig.* 166. Connexion of lead pipe to stoneware pipe by ferrule, wiped and Portland cement joints. *Fig.* 167. Connexion of iron pipe to lead pipe by thimble, wiped and lead-caulked joints. *Fig.* 168. Connexion of stoneware pipe to lead pipe by thimble, wiped and Portland cement joints.

(*i*) The connexion of an iron pipe, trap, or drain with a stoneware pipe, trap, or drain and the connexion of a stoneware trap with a stoneware pipe or drain shall be by a joint made with a gasket of hemp or yarn and cement.

The specified joints are, (1) fused or wiped plumber's, (2) spigot and socket, and (3) flanged. Continuity of the pipe is insisted upon, a precaution designed to prevent the joining of pipes, &c., of unequal diameter or different section, such as the connexion of a 4-in. to a 6-in. pipe without an intermediate enlarging piece (Fig. 164) to ensure continuity of the pipe and flow of liquids.

The connexion of lead to lead, iron to iron, copper to copper, and stoneware to stoneware has been described previously, and these methods obtain whether the connexion is between two pipes, or between a trap and a pipe.

For connecting lead or copper to iron or stoneware a thimble or flanged ferrule is needed. Such thimbles or ferrules are mostly made in cast brass, copper, or gun-metal. Figs. 165 to 172 indicate various connexions.



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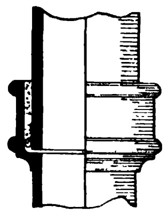

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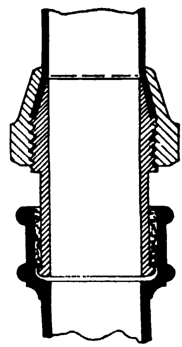

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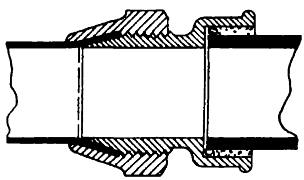

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Fig. 169. Connexion of iron pipe to stoneware pipe by Portland cement joint. *Fig.* 170. Connexion of stoneware pipe to iron pipe by Portland cement joint. *Fig.* 171. Connexion of light copper pipe to iron pipe by ferrule, compressed, screwed, and lead-caulked joints. *Fig.* 172. Connexion of stoneware pipe to light copper pipe by thimble, Portland cement, screwed and compressed joints.

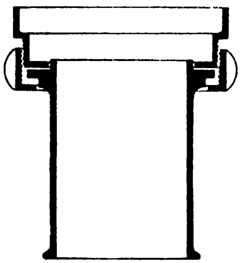
Joints made in an equally suitable and efficient manner with equally suitable materials are accepted. In this category fall joints between lead and stoneware, fire-clay, or pottery such as Doulton's 'Keramic' and Shank's porcelain soldered joint, in which the lead and ware are effectually joined by soldering. Fig. 173 shows a Shank's brass screw coupling with sleeve-piece for connecting with cement to the trap outgo and a lining for wiping on to a lead pipe or caulking into an iron pipe; and Fig. 174 illustrates Macfarlane's joint for lead and iron.

Fixing Soil, Waste, and Ventilating Pipes

Lead pipes can be fixed by means of tacks made of cast or sheet lead wiped on to the pipe and attached to stone,

brick, and concrete walls by galvanized pipe nails, and to woodwork by screws.

Cast-lead tacks are thicker and therefore stronger than those made of sheet lead. For exposed pipes the tacks are usually wiped on to the back (Fig. 175), the method being



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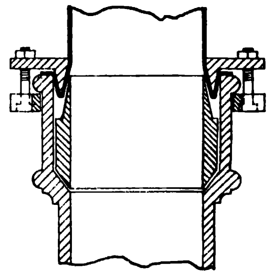

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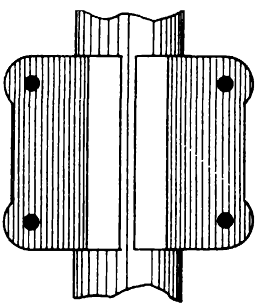
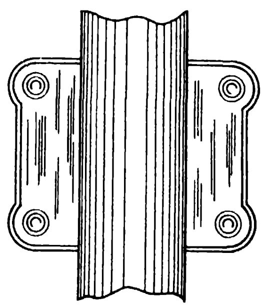
FIG. 173. Shanks's brass screw-coupling and sleeve piece for connecting out-go of ware trap to lead or iron pipe. FIG. 174. Macfarlane's lead and cast-iron pipe joint.





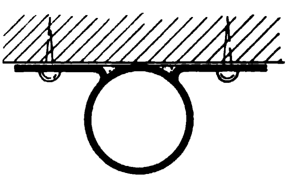
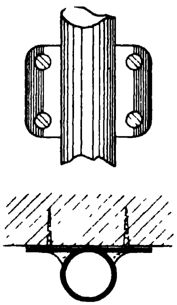


FIG. 175. Front and back views and section of cast-lead fixing tacks wiped to back of pipe.

varied for small-diameter pipes by face-wiping (Fig. 176), and commonly followed for recessed pipes (Fig. 177). If sheet lead is used it should not weigh less than 7 lb. per sq. ft. Sheet-lead tacks are generally fixed by wall-hooks, the tacks being of sufficient area to fold over the hooks, as

in Fig. 178. Tacks are either connected in pairs or singly, not less than two pairs or four singles being employed per 10-ft. length.

Pipes fixed in chases and connected by block joints receive support from the latter, but should have an inter-



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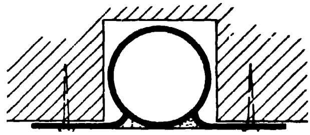

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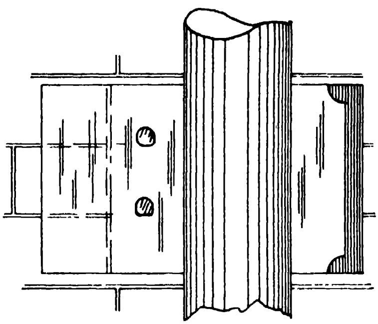
FIG. 176. Face-wiped fixing tacks for lead pipe.
FIG. 177. Face-wiped lead tacks for fixing recessed pipe.



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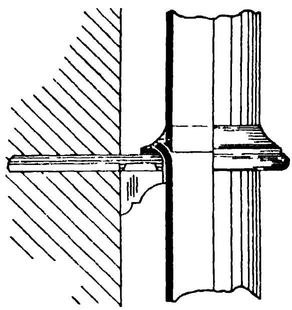

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FIG. 178. Sheet-lead fixing tacks for lead pipe.
FIG. 179. Galvanized-iron or gun-metal brackets for fixing pipe clear of wall.

mediate collar wiped on for support with a maximum intervening distance of 5 ft., or fixed with face-wiped tacks, as in Fig. 177. Alternatively, lead pipes may be fixed by means of galvanized iron or gun-metal brackets of the kind illustrated by Fig. 179, the joints being of the block type with a wiped-on collar and bracket midway. This mode of fixing allows for expansion and contraction without buckling.

All lead pipes require adequate fixings to prevent being

'pulled' away from walls receiving much sun, or being dragged down by their own weight.

Cast-iron pipes used for soil, waste, and ventilating purposes mostly have lugs cast on the sockets and are fastened to the walls, both vertically and horizontally, by pipe nails. If without lugs, holder-bats, as in Fig. 180, are employed.

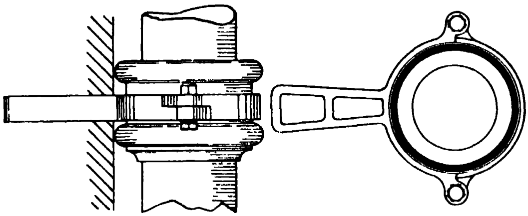


FIG. 180. Malleable iron holder-bat.

Wrought-iron pipes may be fixed by holder-bats fitting under the sockets or couplings with intermediate ones where needed.

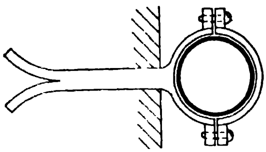
Copper pipes. For small-diameter pipes, copper saddles or clamps are satisfactory. For large pipes, holder-bats, brackets, or batting pipe-bands (Fig. 181) are recommended. If the clip is of iron or steel a band of copper should be inserted between the clip and pipe.

Supports for, and Protection of Drain-pipes

The method adopted is largely determined by the operative by-laws. The Model code[1] specifies that the drain 'shall be properly and suitably supported and protected against injury'; if laid on or in the ground and constructed of material other than cast-iron and constructed or adapted to be used for conveying sewage, or if the nature of the soil renders the precaution necessary it shall, for a distance of at least 50 ft. from a building, be laid on a bed of good concrete. If the drain passes under a building, is laid in the ground, and constructed of material other than heavy cast-iron, it must be completely embedded in and covered with good and solid concrete at least 6 in. thick all round.

[1] Urban, Series IV, 1925.

More explicit requirements are:[1] An iron or stoneware drain must be laid on a concrete bed not less than 6 in. thick, and having a width 12 in. greater than the external diameter of the pipe; and the concrete must be haunched up to not less than half the external diameter of the pipe. If constructed within or under a building a stoneware



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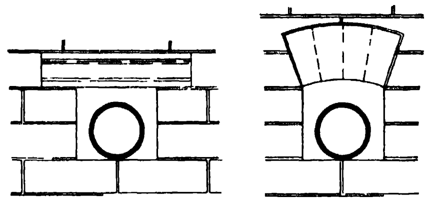

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FIG. 181. Malleable iron pipe bracket or batting band.
FIG. 182. Steel joist or lintel and relieving arch carrying wall over drain pipe.

drain must be encased in concrete at least 6 in. in thickness and an iron drain laid on concrete and haunched as described, unless it be above the ground, when it is sufficient to provide adequate piers at each joint (i.e. one in every 9 ft.) or other sufficient supports such as brackets or holder-bats, or hangers. These requirements practically embody the usual methods of laying or fixing.

An adequate bed or support is indispensable for drains so as to prevent a settlement of the pipes with the consequential damage. Haunching is intended to keep the pipes in position and to strengthen them against superimposed pressure. Where stoneware drains are laid close to the surface of the ground additional protection against heavy traffic and damage should be given by a covering of concrete as required for drains within or under buildings.

In London it is stipulated[1] that where a drain is laid beneath a wall it shall be protected at the part beneath the wall by means of a relieving arch or other support, which shall not bear on the drain; a stipulation which may be met as in Fig. 182.

[1] See footnote on p. 210.

XVI

STRENGTHS, CAPACITIES, DISCHARGING POWERS, AND SIZES OF DRAIN, SOIL, AND WASTE PIPES

Strength of Pipes to resist Internal Pressure

THE strength of water-service pipes to resist a given head or internal pressure must be sufficient to sustain the maximum head plus resistance to shock arising from the sudden arrestation of the flow by quick-closing valves, &c. With soil, waste, and drain pipes, charging with water, on a stoppage, is generally limited to the distance between the point of stoppage and the water-closet, waste fitment, or drain inlet next above. With pipes arranged for fitments on various floors as in Fig. 102, the severity of the test is thus limited.

Latterly there has been a disposition in the case of high buildings to group the conveniences on the top floor, which may be 100–120 ft. above the level where the soil pipe, &c., is connected to the drain. In such cases if a stoppage occurs in the drain or at the base of the vertical pipe the whole of the latter may automatically be brought under a hydraulic test. Consequently it is essential in estimating the required strength of a pipe to have in mind the position of the connected fitments and the maximum test which may at any time be applied.

In addition to the pressure exerted on the walls of the pipe when charged with water by reason of a stoppage in the lower part, the pipe is always liable to shock by the sudden arrest of the momentum of the falling water discharged from fitments at a higher level. What this means may be explained by taking as an illustration a 4-in. diameter soil pipe stopped at the bottom end, with a water-closet discharging, say, two gallons of water at a

height of 30 ft. above the stoppage. The rule for obtaining the theoretical velocity of the falling water is the same as that of a falling body, viz., $V = \sqrt{H} \times 8$; in which H = the head or height in feet and V = the velocity in ft. per second. The square root of 30 is 5·48 and therefore $5{\cdot}48 \times 8$ = a velocity of 43·8 ft. per second. Disregarding the loss of head due to friction, which in this case is negligible, the sudden arrest at the stopped base of the soil pipe of 20 lb. (more or less) of water falling at such a velocity must obviously subject the portion of the pipe wall nearest the point of arrestation to a considerable strain. Provision should therefore be made to meet this shock as well as the head or pressure due to the mere charging of the pipe with water.

The strength of a pipe is governed by the ultimate tensile or cohesive strength of the metal of which it is made and the thickness of the walls.

The ultimate or breaking strength varies considerably, and different authorities select different standards for the purpose of computation. The ultimate strength of soft cast lead at a temperature of 86° F. may be taken as approximating to 1,824 lb. per sq. in.; cast lead, 1,700 to 2,400[1]; and milled lead (sheet and pipe), 2,000 to 3,300, with an average of 2,745 lb. per sq. in. Cast-iron ranges from 13,400 to 22,400, a standard of either 16,000 or 18,000 lb. per sq. in. being generally adopted. The minimum for wrought-iron is put at 49,280 lb., and for copper (annealed) 31,000 lb.

Estimations of the *safe tensile strength* vary from one-fourth to one-tenth of the ultimate strength. Sometimes a differentiation is made between 'safe' and 'working' strength, but the terms may be regarded as synonymous. The safe or working strength is of necessity controlled by the nature of the pressure applied, whether gradual and limited to the actual head of water as provided by slow filling of the pipe, or sudden, such as the arrest of the

[1] Trautwine puts the average at 2,050 lb. *The Civil Engineer's Pocket Book.*

momentum of a column of falling water or the action of quick-closing valves. In some cases it is put at one-sixteenth of the ultimate or breaking strength. Box and other well-known authorities suggest that to provide against internal shock and variations in the thickness of the metal forming lead pipe, it should be taken at not less than one-tenth.[1] This factor of safety may be accepted as meeting all normal circumstances.

Lead-pipe manufacturers mostly take the safe strength as one-fifth of the ultimate strength. For safety's sake it may, however, be reckoned as one-tenth, which factor has been adopted for Table No. X. For the purpose of comparison the same factor of safety (one-tenth) has also been used for Tables Nos. XI, XII, and XIII, relating respectively to cast-iron, wrought-iron, and copper, but as these metals (unlike lead) do not 'creep' under a continuously applied load, the ratio of safe to ultimate strength may, without risk, be put at one-fifth.

The B.E.S.S.[2] recommends that the tensile breaking strength of the metal for cast-iron sewage pipes should not be less than 9½ tons (21,280 lb.) per sq. in.; and that the working pressure should not exceed one-half of the test pressure (see p. 247).

Rules or formulae given by accepted authorities for ascertaining the required pipe-wall thickness to withstand a specified head or pressure plus the necessary allowance for shock, or conversely the safe pressure which may be applied to pipe walls of a given thickness, show extreme divergencies. Almost without exception they are based on the use of pipes, such as water-mains, for conveying water under a continuous, though maybe a varying, pressure.

Lead Pipes

Much misconception prevails as to the strength of pipes made of this metal, with the result that an undue strain is sometimes placed on the metal even if the pipes are not

[1] *Practical Hydraulics*, p. 78. Box.

[2] British Engineering Standards Association, Specification No. 78, 1917.

actually burst or fractured. The following rule is used by some lead-pipe manufacturers:

(1) $P = \dfrac{F \times 2T}{A}$; and $T = \dfrac{P \times A}{F \times 2}$;

where

P = bursting pressure in lb. per sq. in.
F = tensile strength in lb. per sq. in.
T = wall thickness of pipe in decimals of an in.
A = internal diameter of pipe in inches.

For thick-walled pipes Barlow's rule[1] is:

(2) $T = \dfrac{R \times P}{S - P}$; $P = \dfrac{S \times T}{R + T}$; and $S = \dfrac{(R + T) \times P}{T}$;

One rule for comparatively thin pipes is:

(3) $T = \dfrac{P \times R}{S}$ and $P = \dfrac{S \times T}{R}$.

In (2) and (3) rules:

S = cohesive strength of the metal in lb. per sq. in.
P = internal pressure per sq. in., in the same terms as S.
R = radius of the inside of the pipe in inches.
T = thickness of the metal in inches.

Rule (3) though somewhat differently expressed gives identical results with rule (1).

As an example of the working of rule (3), a 2-in. diameter pipe having the minimum wall thickness given in Table No. X, p. 284 (0·102 in.), may be selected with the assumption of an ultimate strength of 2,745 lb. and a factor of safety of one-tenth.

Then $P = \left(\dfrac{2745 \times 0{\cdot}102}{1}\right) \div 10 = 28$ lb. safe pressure per sq. in. or a safe head of 64·5′ ft.

and $T = \left(\dfrac{28 \times 1}{2745}\right) \times 10 = 0{\cdot}102$ in.

[1] *Practical Hydraulics*, p. 72. Box. This rule applies to metal pipes generally.

The following table is based on rule (3), the ultimate strength of lead being taken at 2,745 lb. per sq. in. and the safe strength as one-tenth of the ultimate strength:

TABLE NO. X[1] *giving the approximate weight, thickness of metal, safe internal pressure in lb. per sq. in., and safe head in feet for* LEAD PIPES.

(*Note.*—The weights given are those equal to or greater than the minima prescribed by certain by-laws,[2] the *minimum weights* being shown in heavy type.)

Internal diameter of pipe in inches.	*Weight per yard in lb.*	*Thickness of walls in decimals of an inch.*	*Safe internal pressure in lb. per sq. in.* $\left(\frac{S \times T}{R}\right) \div 10$ $S = 2{,}745$	*Safe head in ft.-lb. pressure.* $\div 0{\cdot}4335$.
1	**5**	**0·099**	**54·5**	**125**
	$5\frac{1}{2}$	0·107	58·5	135
	6	0·115	63·0	145
	7	0·133	73·0	168
	$7\frac{1}{2}$	0·141	77·5	178
	8	0·150	82·5	190
	$8\frac{1}{2}$	0·158	86·5	200
	9	0·166	91·0	210
	$9\frac{1}{2}$	0·174	95·5	220
	10	0·182	100·0	230
	$10\frac{1}{2}$	0·190	104·3	240
$1\frac{1}{4}$	$\mathbf{6\frac{1}{4}}$	**0·100**	**44·0**	**101**
	7	0·110	48·5	111
	$7\frac{1}{2}$	0·118	52·0	119
	8	0·125	55·0	126
	9	0·139	61·0	140
	10	0·153	67·0	155
	$10\frac{1}{2}$	0·160	70·5	162
	11	0·167	73·5	169
	12	0·180	79·0	182
	$12\frac{1}{2}$	0·187	82·0	189
	13	0·193	85·0	195
$1\frac{1}{2}$	$\mathbf{7\frac{1}{2}}$	**0·097**	**35·5**	**82**
	9	0·119	43·5	100
	10	0·132	48·5	111
	$10\frac{1}{2}$	0·138	50·5	116
	11	0·144	52·5	121
	12	0·156	57·0	130
	$12\frac{1}{2}$	0·162	59·5	136
	13	0·168	61·5	141
	14	0·180	66·0	151
	15	0·191	70·0	161

[1] This table is based on weights and thicknessess of lead pipes made by Messrs. Locke, Lancaster, and W. W. and R. Johnson and Sons, Ltd., to whom the Author is indebted.

[2] See footnote on p. 210

Internal diameter of pipe in inches.	Weight per yard in lb.	Thickness of walls in decimals of an inch.	Safe internal pressure in lb. per sq. in. $\left(\frac{S \times T}{R}\right) \div 10$ $S = 2{,}745$	Safe head in ft.-lb. pressure. $\div 0{\cdot}4335$
$1\frac{3}{4}$	**$8\frac{3}{4}$**	**0·102**	**32·0**	**74**
	14	0·158	49·5	114
	15	0·168	52·5	121
	16	0·178	55·5	128
	17	0·189	59·5	134
	18	0·199	62·5	144
	20	0·218	68·5	157
	21	0·228	71·5	164
	22	0·238	74·5	172
	24	0·257	80·5	185
	28	0·295	92·5	213
2	**10**	**0·102**	**28·0**	**64**
	12	0·121	33·0	76
	14	0·141	38·5	89
	15	0·151	41·5	95
	16	0·160	44·0	101
	18	0·178	49·0	112
	19	0·188	51·5	119
	20	0·197	54·0	124
	21	0·205	56·0	129
	22	0·214	58·5	135
$2\frac{1}{2}$	**$12\frac{1}{2}$**	**0·103**	**22·5**	**52**
	$13\frac{1}{2}$	0·111	24·5	56
	15	0·123	27·0	62
	21	0·169	37·0	85
	22	0·177	39·0	89
	24	0·192	42·0	97
	25	0·199	43·5	100
	27	0·214	47·0	108
	28	0·222	48·5	112
	29	0·229	50·5	115
	30	0·237	52·0	119
	32	0·252	55·5	127
	$33\frac{1}{2}$	0·262	57·5	132
3	**15**	**0·104**	**19·0**	**43**
	$15\frac{9}{10}$	0·110	20·0	46
	$16\frac{1}{2}$	0·114	21·0	48
	$17\frac{1}{10}$	0·118	21·5	50
	18	0·124	22·5	52
	$20\frac{2}{5}$	0·140	25·5	59
	$22\frac{1}{5}$	0·151	27·5	63
	24	0·163	30·0	68
$3\frac{1}{2}$	**$19\frac{1}{2}$**	**0·116**	**18·0**	**42**
	21	0·125	19·5	45
	24	0·142	22·0	51
	27	0·159	25·0	57

Internal diameter of pipe in inches.	*Weight per yard in lb.*	*Thickness of walls in decimals of an inch.*	*Safe internal pressure in lb. per sq. in.* $\left(\frac{S \cdot T}{R}\right) \div 10$ $S = 2{,}745$	*Safe head in ft.-lb. pressure.* $\div 0{\cdot}4335$
4	**$22\frac{1}{2}$**	**0·118**	**16·0**	**37**
	$22\frac{4}{5}$	0·119	16·5	37
	24	0·125	17·0	39
	$26\frac{1}{10}$	0·136	18·5	42
	27	0·140	19·0	44
	$29\frac{2}{5}$	0·152	20·5	47
	30	0·155	21·0	48
	$32\frac{1}{10}$	0·168	23·0	53
	$33\frac{2}{5}$	0·173	23·5	54
$4\frac{1}{2}$	**29**	**0·135**	**16·5**	**37**
	30	0·139	17·0	39
	32	**0·149**	**18·0**	**42**
	$33\frac{3}{5}$	0·155	19·0	43
	42	0·193	23·5	54
	51	0·232	28·5	65
	52	0·236	29·0	66
	60	0·271	33·0	76
	66	0·296	36·0	83
	69	0·309	37·5	86
	70	0·313	38·0	87
	75	0·334	40·5	93
	77	0·343	42·0	96
	80	0·355	43·5	99
5	**$35\frac{1}{2}$**	**0·149**	**16·5**	**37**
	41	**0·171**	**18·5**	**42**
	45	0·187	20·5	47
	64	0·262	28·5	66
	65	0·266	29·0	67
	66	0·270	29·5	68
	72	0·293	32·0	74
	75	0·305	33·5	77
	76	0·308	33·5	77
	77	0·312	34·0	78
	82	0·331	36·5	83
	84	0·339	37·0	85
	85	0·343	37·5	86
	90	0·362	40·0	92
6	**50**	**0·175**	**16·0**	**37**
	57	**0·198**	**18·0**	**42**
	60	0·208	19·0	43
	66	0·228	21·0	47
	69	0·238	21·5	50
	70	0·241	22·0	51
	72	0·248	22·5	52
	84	0·287	26·0	60
	99	0·336	30·5	70

As will be seen from the table, pipes from $1\frac{1}{2}$ in. diameter upwards of the weights ordinarily used for soil- and waste-pipes have a safe strength below 100 ft. head. If the factor of safety is taken at one-fifth instead of one-tenth of the ultimate strength (as suggested by some manufacturers), the safe head is still, in the case of the lighter weights of 3- to 6-in. pipes, below 100 ft. Against such relatively low safe strengths can, however, be put the circumstance that in the large majority of works the maximum head applicable is, as stated on p. 280, restricted by the position of the fitments. Where fitments are placed on an upper floor with a height between the lowest connexion and the bottom of the pipe exceeding the safe head given in the table, the weight of the pipes should be sufficiently increased, or cast-iron pipes used in place of lead.

Cast-iron Pipes

One rule for ascertaining the thickness of cast-iron pipes is that given by Fanning:[1]

$$(4)\quad T = \frac{(P+100)\times D}{0{\cdot}4S} + 0{\cdot}333\left(1 - \frac{D}{100}\right),$$

where

T = thickness of pipe wall in inches for a safe working pressure.

P = pressure in lb. per sq. in.

100 = an addition to the pressure to allow for water-ram or shock, irregularity of casting, &c.

D = internal diameter of pipe in inches.

S = ultimate tensile strength in lb. per sq. in.

0·333 = factor of safety.

For ascertaining the pressure the rule becomes:

$$(5)\quad P = \left(\frac{0{\cdot}4S\times T - 0{\cdot}1332\,S\times\left(1 - \frac{D}{100}\right)}{D}\right) - 100.$$

[1] *The Civil Engineer's Pocket Book*, p. 512. Trautwine.

Box suggests[1] that Barlow's rule (2) is quite inapplicable to thin cast-iron pipes and therefore substitutes an empirical rule as follows:

$$(6)\quad T = \left(\frac{\sqrt{D}}{10} + 0{\cdot}15\right) + \left(\frac{H \times D}{25000}\right),$$

in which

D = diameter of the pipe in inches.
H = safe head of water in feet.
T = thickness of the metal in inches.

From this rule the safe head in feet can be ascertained, i.e.:

$$(7)\quad H = \frac{25000}{D} \times \left(T - \frac{\sqrt{D}}{10} - 0{\cdot}15\right).$$

Rules (4) to (7) provide for a strength of pipe capable of withstanding crushing by road traffic, a provision much in excess of that needed for soil and waste pipes and pipes used for domestic drainage in ordinary situations, and therefore are inapplicable to thin pipes or light castings of a thickness or weight recognized as sufficient for the latter purposes. As an indication of inapplicability it may be pointed out that on Box's rule a 4-in. diameter soil-pipe for 100 ft. head (43 lb. per sq. in.) would need to be 0·37 in. in thickness, which thickness on Barlow's rule with a factor of safety of 10 would sustain a pressure approximating to 281 lb. per sq. in. and on rule (3) 333 lb.

Rule (3) would appear to give the most accurate results having regard to the use of the pipes. Table No. XI is based on this rule, the tensile strength of the metal being taken as 18,000 lb. per sq. in.

From the table it may be judged that soil, waste, and drain pipes of the weight and thickness given are sufficiently strong to withstand any internal pressure to which in ordinary circumstances they are likely to be subjected by the automatic application of a hydraulic test on the occurrence of a stoppage.

[1] *Practical Hydraulics*, p. 73. Box.

TABLE NO. XI *giving the approximate weight, thickness of metal, safe internal pressure in lb. per sq. in., and safe head in feet for* CAST-IRON PIPES. (*Note.*—The minimum weights prescribed by certain by-laws—see footnote on p. 210—are shown in heavy type.)

Internal diameter of pipe in inches.	*Weight per length in lb.*	*Thickness of metal or pipe wall in fractions of an inch and the decimal equivalents.* Fractions.	Decimals.	*Safe internal pressure in lb. per sq. in.* $\left(\frac{S \times T}{R}\right) \div 10$ $S = 18{,}000$	*Safe head in ft.-lb. pressure* $\div 0{\cdot}4335$
Soil and soil-ventilating pipes and waste and waste-ventilating pipes in 6 ft. lengths					
1½	**22**	3/16	**0·1875**	**450**	**1,038**
	24	1/4	0·25	600	1,384
2	**24**	3/16	**0·1875**	**337**	**778**
	27	13/64	0·203	365	842
	32	1/4	0·25	450	1,038
2½	**30**	3/16	**0·1875**	**270**	**622**
	33	13/64	0·203	292	674
	38	1/4	0·25	360	830
3	**35**	3/16	**0·1875**	**225**	**519**
	40	13/64	**0·203**	**243**	**561**
	47	1/4	0·25	300	692
3½	**41**	3/16	**0·1875**	**192**	**444**
	48	13/64	**0·203**	**208**	**481**
	54	1/4	0·25	257	593
4	**47**	3/16	**0·1875**	**168**	**389**
	54	13/64	**0·203**	**182**	**421**
	60	1/4	0·25	225	519
4½	**54**	3/16	**0·1875**	**150**	**346**
	63	13/64	0·203	162	374
	66	1/4	**0·25**	**200**	**461**
5	**59**	3/16	**0·1875**	**135**	**311**
	69	13/64	0·203	146	337
	78	1/4	**0·25**	**180**	**415**
6	**71**	3/16	**0·1875**	**112**	**259**
	84	7/32	0·2187	131	302
	92	1/4	**0·25**	**150**	**346**
Drain-pipes in 9-ft. lengths unless otherwise stated					
3	110	5/16	0·3125	375	865
	70 (6 ft.)	3/8	0·375	450	1,038
3½	80 (6 ft.)	3/8	0·375	386	889
4	**160**	3/8	**0·375**	**337**	**778**
4½	160	3/8*	0·375	300	692
5	**190**	3/8	**0·375**	**270**	**622**
6	**230**	3/8	**0·375**	**225**	**519**
	292	1/2	0·5	300	692
7	**350**	7/16	**0·4375**	**225**	**519**
	353	1/2*	0·5	257	592
8	**400**	7/16	**0·4375**	**197**	**454**
	402	1/2*	0·5	225	519
9	**450**	7/16*	**0·4375**	**175**	**403**
	452	1/2	0·5	200	461

* Nominal thickness of metal.

Neither the public health by-laws nor the B.E.S.S.[1] prescribe a standard test for cast-iron soil, waste, or drain pipes. The last mentioned, however, includes a requirement for a test pressure before coating of 400 ft. head for 3- to 9-in. diameter spigot and socket pipes for water or sewage weighing from 129 to 485 lb. per 9-ft. length.

Wrought-iron and Copper Pipes

Similarly based on Rule (3) wrought-iron and copper pipes of the thickness given in Tables Nos. XII and XIII are adequate in strength to meet the maximum pressure to which usage as soil or waste pipes may subject the metal.

TABLE NO. XII *giving the approximate weight, thickness of metal, safe internal pressure in lb. per sq. in., and safe head in feet for standard* WROUGHT-IRON PIPES *of water strength.*

Internal diameter of pipe in inches.	*Weight per ft in lb.*	*Approximate thickness of metal or pipe wall.* *Imperial Standard Wire Gauge.*	*Decimals of an inch.*	*Safe internal pressure in lb. per sq. in.* $\left(\frac{S \times T}{R}\right) \div 10$, $S = 49{,}280$	*Safe head in ft.-lb. pressure* $\div 0{\cdot}4335$
1	1·78	9	0·144	1,419	3,273
1¼	2·6	8	0·160	1,261	2,908
1½	3·25	7	0·176	1,156	2,666
1¾	3·8	7	0·176	991	2,286
2	4·5	7	0·176	867	2,000
2½	5·775	6	0·192	756	1,744
3	6·851	6	0·192	630	1,453
3½	7·759	6	0·192	540	1,246
4	8·723	6	0·192	473	1,091
5	11·01	6	0·192	378	872
6	13·601	6	0·192	315	727

The B.E.S.S. provides[2] that low-pressure pipes conforming with the particulars in Table XIII (A) must be subjected to an internal hydraulic pressure test of 300 lb. per sq. in.

[1] British Engineering Standards Association, Specification No. 78, 1917.
[2] *Ibid.*, Specification No. 61, 1913.

TABLE No. XIII *giving the approximate weight, thickness of metal, safe internal pressure in lb. per sq. in., and safe head in feet for* COPPER PIPES:

(A)—*British Standard Specification*[1] *for pipes with screwed connexions for working pressures up to a hydraulic head of 120 ft.*

(B)—*Ministry of Health's Specification for pipes having suitable and efficient joints, not being screwed.* (Model By-laws, Series XXI.)

(C)—*Suggested Specification of minimum weights, &c., for pipes with compression joints for use as soil and soil-ventilating and waste and waste-ventilating pipes.*

Internal diameter of pipe in inches.	*Weight per yard in lb.*	*Approximate thickness of metal or pipe wall.* I.S.W.G.	*Decimals of an inch.*	*Safe internal pressure in lb. per sq. in.* $\left(\frac{S \times T}{R}\right) \div 10$ $S = 31{,}000$	*Safe head in ft.-lb. pressure* $\div 0.4335$.
		(A)			
1	3·12	14	0·080	496	1,144
$1\frac{1}{4}$	3·87	14	0·080	396	915
$1\frac{1}{2}$	4·59	14	0·080	330	762
$1\frac{3}{4}$	6·15	13	0·092	325	751
2	6·99	13	0·092	285	657
$2\frac{1}{2}$	8·64	13	0·092	228	526
3	11·70	12	0·104	214	495
$3\frac{1}{2}$	15·21	11	0·116	205	473
4	19·17	10	0·128	198	457
		(B)			
1	2·13	17	0·056	347	800
$1\frac{1}{4}$	2·64	17	0·056	277	640
$1\frac{1}{2}$	3·15	17	0·056	231	533
$1\frac{3}{4}$	4·20	16	0·064	226	522
2	4·80	16	0·064	198	457
$2\frac{1}{2}$	5·94	16	0·064	158	366
3	8·04	15	0·072	148	343
$3\frac{1}{2}$	10·38	14	0·080	141	326
4	13·65	13	0·092	142	328
		(C)			
1	1·83	18	0·048	297	686
$1\frac{1}{4}$	2·25	18	0·048	238	549
$1\frac{1}{2}$	2·70	18	0·048	198	457
$1\frac{3}{4}$	3·66	17	0·056	198	457
2	4·17	17	0·056	173	400
$2\frac{1}{2}$	5·19	17	0·056	138	320
3	7·11	16	0·064	132	304
$3\frac{1}{2}$	9·33	15	0·072	127	294
4	11·85	14	0·080	124	286
$4\frac{1}{2}$	13·29	14	0·080	110	253
5	14·76	14	0·080	99	228
6	17·64	14	0·080	82	189

[1] See footnote 2, p. 290.

Glazed Stoneware Pipes

To comply with the B.E.S.S. and certain by-laws[1] the pipe walls must be of the minimum thickness given in Tables Nos. VI and VII, on p. 259. The former provides for[2] the application of a hydraulic test of 20 lb. per sq. in. (about 46 ft. head of water), the pressure to be applied at a rate not exceeding 10 lb. per sq. in. in five seconds. First-quality pipes will withstand a much greater pressure, for 6-in. diameter pipes of 'Vitrifine'[3] stoneware selected haphazard from stock on subjection to a test did not burst until a pressure of 250 lb. per sq. in. was applied.

The test pressure specified by the B.E.S.S. should be accepted as indicating the safe working head in practice if specially strong joints are used. If the pipes have plain cement or bitumen joints a head in excess of 30 ft. is risky and therefore undesirable. In such circumstances cast-iron pipes should take the place of stoneware.

Crushing Strength of Pipes

In addition to providing against the bursting of pipes by internal pressure it is essential that the pipes should be sufficiently strong to stand reasonable usage as expressed by pressure being applied externally.

A 2-in. diameter lead pipe so fixed that the maximum head applicable is limited to 20 ft., or less than 9 lb. per sq. in., need be but 0·033 in. thick per the rule:

$$T = \frac{9 \times 1}{2745} \times 10 = 0{\cdot}033 \text{ in.}$$

Such a thickness is equivalent to 2-lb. lead, which could hardly be regarded as adequate to withstand rough knocks or the effects of any considerable variations in temperature.

[1] See footnote on p. 210.
[2] British Engineering Standards Association, Specification No. 65, 1914. This pressure is applied by Messrs. Doulton and Co., Ltd., to their 'Tested' pipes.
[3] Messrs. John Knowles & Co. (London), Ltd.

Similarly, a 4-in. diameter cast-iron pipe made of metal with a safe tensile strength of 1,800 lb. $\left(\frac{18000}{10}\right)$ needs pipe walls of a thickness of only 0·0482 in. to sustain a head of 100 ft. or 43·4 lb. per sq. in., for:

$$T = \left(\frac{43{\cdot}4 \times 2}{18000}\right) \times 10 = 0{\cdot}0482 \text{ in.}$$

It must not, however, be concluded that such a pipe is suitable for the suggested use, for it is too thin to withstand rough handling and a reasonable external pressure. Moreover, the walls are much too thin to allow of the joints being caulked with metallic lead.

Hence in determining the sufficiency of pipe walls the probability of external pressure cannot be ignored, a point recognized in the stated thicknesses in by-laws and the B.E.S.S. which are designed to provide pipes capable of resisting both internal and external pressure and allowing for effectual jointing.

The B.E.S.S.[1] prescribes a transverse or beam test of the metal used for making cast-iron pipes for water and sewage, a bar of the metal being cast for the purpose 3 ft. 6 in. in length, 2 in. deep, and 1 in. wide, placed edgeways on knife edges 3 ft. apart. The bars must sustain a load of 28 cwt. applied at the centre.

It is also stipulated[2] that copper pipes must stand drifting without showing crack or flaw until the diameter of the drifted end measures at least 25 per cent. more than the original diameter, and stand without crack or flaw, both cold and at red heat, complete flattening and doubling over on itself.

Uniform tests made[3] on lead and copper pipes for the purpose of ascertaining the blow (in foot-pounds) required

[1] British Engineering Standards Association, Specification No. 78, 1917.

[2] *Ibid.*, No. 61, 1913.

[3] *The Use of Copper and Brass for Domestic Water Services*, Copper and Brass Extended Uses Council.

to diminish the cross-sectional area by 10 per cent. show results as follows:

Internal diameter of pipe in inches.	*Thickness of metal or pipe wall.*		*Blow (in ft.-lb.) to reduce area by 10 per cent.*	
	Gauge.	*Inch.*	*Copper.*	*Lead.*
½	18	0·048	15	—
		0·2	—	5·4
¾	18	0·048	18	—
		0·2	—	11
1	17	0·056	24	—
		0·21	—	17·5
1½	17	0·056	30	—
		0·3	—	28

Stoneware pipes can be tested by placing a loaded beam along the suitably supported barrel. Actual tests show that a first-quality pipe will require a weight of 1·66 to 1·9 tons to crush. There are, however, such wide divergencies in results owing to the varying methods of applying the test in respect of the length and width of the bearing surfaces and the manner in which the pipe is bedded that results which can fairly be regarded as representative are not obtainable.

Strength of Joints

As it is both customary and essential that pipes should be tested *in situ* the method of jointing must be of a kind capable of resisting the hydraulic head or pressure applied. A wiped joint on a lead pipe is much stronger than the pipe itself.

The screwed joints of wrought-iron pipes and the flange and lead-caulked joints of cast-iron pipes are strong enough to stand the pressures usually applied. Lead-caulked joints on pipes subjected to large variations of temperature as set up by the carriage of hot water or exposure to direct sun heat are, however, sometimes affected owing to the greater expansion of the lead compared with iron, the result being that the lead is pushed or squeezed out. This tendency should be prevented by the adoption

of a good retaining socket, such as the 'Pam' previously mentioned, and the use of lead wool in preference to molten lead.

Joints properly made with 'Ribbonite' or 'Lead wool' will stand a pressure in excess of 1,500 lb. and a run-lead caulked joint up to 800 lb. per sq. in. Macfarlane's special joint for lead and iron (Fig. 174) will stand a pressure of 86·7 lb. (200 ft. head) per sq. in.

Rust joints, if properly made, will resist a fair head of water; but the joints of iron pipes made with red and white lead mastic or Portland cement are unreliable under slight pressures for the reasons before stated.

The compression joints for copper pipes illustrated by Figs. 151 to 154 may be depended upon to stand the maximum hydraulic head applied under low pressures.

As indicated on p. 292 the weakness of stoneware pipe work is in the joints. Plain cement joints cannot be expected to stand an internal pressure in excess of about 30 ft. (13 lb. per sq. in.); but certain special joints will resist greater strain. Tests made have disclosed the fact that Doulton's grouted composite joint can well withstand 35 ft. head; and the 'Yarrow' joint (Fig. 157) a sustained head of 40 lb. per sq. in. (92 ft. head); while for Ames and Crosta's joint it is claimed that it has withstood a hydraulic pressure which has been sufficient to burst the pipes. Doulton's 'Keramic' joint is tested under a pressure of 45 lb. per sq. in.

Absorption Test for Salt-glazed Ware Pipes

The B.E.S.S.[1] lays down an absorption test as follows: 'The test pieces selected for testing shall be taken from the body of the pipe and not within 6 in. of the end. Each test piece shall be of the whole thickness of the pipe, and shall have two glazed surfaces, each having an area of not less than 8 in. super nor more than 20 in. super. The test pieces shall be dried at a temperature of not less

[1] British Engineering Standards Association, Specification No. 65, 1914.

than 150° C. (302° F.) until no further loss of weight can be noted. They shall then be immersed in cold water, and the temperature raised to boiling-point (100° C.). The water shall be maintained at that temperature for one hour, and after it has been allowed to cool the test pieces shall be removed, carefully wiped with a dry cloth, and then re-weighed. The percentage increase in weight of each test piece by absorption of water shall not exceed the figures given in the following Table,' i.e.:

Thickness of pipe.	*Percentage increase in weight.*
¾ in. and under . . .	5
Over ¾ in. and up to 1 in. .	6
Over 1 in. and up to 1½ in. .	8
Over 1½ in	10

Good pipes easily conform with this standard, various tests showing that the water absorbed is frequently less than 3 per cent.

Specified Sizes of Pipes for Particular Purposes

The Model code of by-laws[1] stipulates a minimum internal diameter of 4 in. for sewage drains, 3 in. for drain-ventilating pipes, and 3½ in. for soil pipes and waste pipes from slop-sinks. Under the Public Health Act, 1875, the sanitary authority can require drains to be of such materials and size and to be laid at such level and fall as may appear to be necessary.

Suggested minimum pipe sizes are 4 in. for drains; 3½ in. for drain-ventilating and soil pipes; 3 in. for slop-sinks; 1½ in. for a single urinal basin and 2 in. for not more than two stalls or basins; and 1½ in. for a bidet. If iron or stoneware are used for waste pipes from baths, lavatory basins, sinks, &c., the minimum size should be 1½ in. Main ventilating pipes to be of the same diameter as the soil- or waste-pipe. Trap ventilating pipes to be at least 2 in. for water-closets and slop-sinks; 2 in. for urinals where these are connected with a soil pipe or where the

[1] Urban, Series IV, 1925.

waste pipe is 3 in. or more in diameter; and two-thirds of the respective internal diameters of the branch and main waste pipes from urinals, bidets, baths, lavatory basins, and sinks where the waste pipes are less than 3 in.

Under the Metropolis Management Act, 1855, and the London County Council (General Powers) Act, 1920, the local authorities in London (i.e. the Metropolitan Borough Councils) can prescribe respectively for existing and newly-erected buildings the size, level, and fall of the drains, which technically include soil, waste, and rain-water pipes, and may therefore require the use of pipes larger than the minima quoted in the by-laws if such are needed to provide adequate drainage.

Small *v.* Large Pipes

All pipes taking sewage or foul liquids should be as small as is compatible with the volume to be conveyed; a self-cleansing condition with the minimum content for the accumulation of gases being aimed at. If pipes unnecessarily large are used an extensive fouling surface is provided and solids are likely to be deposited owing to the shallow depth or small volume of the flowing liquid. Pipes too large for the work to be performed are not infrequently reduced in sectional area by the accumulation of solid matters to an area sufficient for the usual discharges. As instances may be quoted rectangular brick drains of 9 in. or more in internal diameter reduced to one-half or one-third the original size, and 6-in. soil pipes to as little as 3 in.

Capacity of Pipes

The capacity of a pipe is merely the cubic content in feet or gallons, and is ascertained by multiplying the sectional area by the length. In the case of circular pipes the contents in gallons per foot run equals the diameter in inches squared $\times$ 0·034, and the weight of water in lb. per foot run the diameter in inches squared $\times$ 0·34.

The relative capacity of pipes is as the squares of their diameters, e.g. a 4-in. pipe has four times the capacity of a 2-in. pipe, for $4 \times 4 = 16$, and $2 \times 2 = 4$.

Relative Discharging Powers of Pipes

The discharging powers of pipes are affected by the retardation of flow due to friction against the pipe surface, and consequently the relationship between pipes of

TABLE No. XIV *giving the approximate relative discharging powers of pipes of various diameters.*

Diameter of pipe in inches.														
9	8	7	6	5	4½	4	3½	3	2½	2	1¾	1½	1¼	1
1	1·3	1 8	2 8	4·3	5 6	7 2	10 5	15 5	24·5	43 4	60 7	90 0	143 0	243·0
	1	1·4	2 0	3 2	4 2	5·6	8 0	11·6	18·2	32·3	45 2	67 0	106 0	181·0
		1	1·5	2·3	3 0	4·0	5 0	8·3	13 0	23·2	27·5	48 0	76 0	130·0
			1	1·6	2 0	2·7	3 8	5 6	9·0	16·0	22 0	32 5	52·0	88·0
				1	1 3	1 7	2 4	3 6	5·6	10 0	14·0	20·7	33 0	56·0
					1	1·3	1 8	2·7	4 3	7 6	10 7	16·0	25 2	43 0
						1	1 4	2 5	3 2	5 7	8 0	11 8	18 8	32·0
							1	1·5	2 3	4 1	5·7	8 5	13 0	23·0
								1	1 5	2 8	3 9	5 8	9 0	15 6
									1	1 7	2 5	3 7	5·8	9 9
										1	1 4	2 0	3 2	5 6
											1	1 5	2 3	4 0
												1	1 5	2·7
													1	1 7

different diameters is different to that indicated by the relative capacity. The discharging power is as the square root of the fifth power of the diameter. Table No. XIV is calculated on this rule, the diameters selected being those given in Table No. IV on p. 248.

Fall of, Velocity of Flow through, and Discharge from Drain Pipes

Sewage drains have to carry not only solid and liquid faecal matter and water fouled by domestic use, but also sand and other detritus derived from the cleaning of pots and pans, &c., in sculleries and washhouses, and, where the drainage system is on the combined principle, the washings from roofs and paved surfaces. According to

Trautwine[1] the velocity necessary for carrying off detritus and leaving the drain free from deposits is a minimum of 240 ft. per minute for 4-in. and 220 ft. for 6- to 9-in. pipes.

The modern rough-and-ready practice most closely followed is to compute the fall by multiplying the internal diameter of the pipe in inches by 10, assuming the result as the length in feet for one foot fall. This gives an easily remembered rule, and provides—as seen in Table No. XV—a uniform velocity of 253 ft. per minute when the pipes are running either full or half full.

Eytelwein's rule for ascertaining the velocity produced by a known head is:

$$V = 54\sqrt{2Fh},$$

in which

V = velocity of flow in feet per minute,
F = fall in feet per mile, and
h = hydraulic mean depth, or the sectional area in feet of the liquid divided by the length of the wetted perimeter of the pipe.

To convert velocity into gallons the rule is:

$G = V \times d^2$ in ft. $\times 4{\cdot}9$; or
$G = V \times d^2$ in in. $\times 0{\cdot}034$.

When flowing full bore the hydraulic mean depth equals the diameter of the pipe in feet $\div$ 4, and the same when running but half full. At depths of less than half the diameter the velocity diminishes, being, at a depth of 0·25 diameter, only 0·78 of that when full, with a still more marked decrease with lesser depths. *Per contra*, depths in excess of half the diameter give an increase in velocity, the maximum being attained at a depth of 0·9 of the diameter with a velocity 10 per cent. greater than when running either full or half full. Table No. XV is based on Eytelwein's rule.

Size of Drains for Specified Purposes

Drains are all too frequently constructed of a size much in excess of that needed for the maximum volumetric

[1] *The Civil Engineer's Pocket Book*, p. 575. Trautwine.

discharge, 6- and 9-in. pipes being used where 4- and 6-in. would be adequate. In computing the size of a drain the controlling factors are the volume of sewage to be carried under working conditions plus, where the drain is intended to receive rain- and surface-water, the maximum amount to be disposed of in a given period.

TABLE NO. XV *giving approximate velocity of flow through, and discharge in gallons from, drain pipes running full or half full.*

Diameter of pipe in feet.	*Diameter of pipe in inches.*	*H.M.D. in feet.*	*Fall in feet. One foot in—*	*Fall in feet per mile.*	*Velocity in feet per minute.*	*Discharge in gallons per minute when running—*	
						Full.	*Half full*
0·3333	4	0·0833	40	132	253	138	69·0
0·4167	5	0 1042	50	106	253	215	107·5
0·5	6	0·125	60	88	253	310	155·0
0·5833	7	0·1458	70	75	253	421	210 5
0·6667	8	0·1667	80	66	253	550	275·0
0 75	9	0·875	90	59	253	697	348·5

A usual method of computation is to take the water-supply per head per diem, assume that half the daily flow of the resulting sewage occurs within six hours, and add the volume of rainfall receivable into the system. If the water-supply is taken at 40 gallons per head per diem the estimate will meet most cases; but the determination of the provision to be made for rainfall is less easy inasmuch as it should provide for extreme conditions. In these islands a rainfall exceeding a rate of $2\frac{1}{2}$ in. per hour is classifiable as one of very rare intensity, and therefore if a rate of 4 in. an hour is allowed the provision may be regarded as meeting an unusual condition. A fall of 4 in. per hour represents one-fifteenth of an inch of rain per minute and is the equivalent of $\frac{6{\cdot}25}{12 \times 15}$ ·0347 of a gallon per sq. ft. of surface.

With the water-supply and the rainfall as the controlling

factors an example may be selected for the purpose of ascertaining the size of the drain required.

Example 1. An ordinary type of villa occupied by ten persons and fitted with two w.c.'s., a bath, lavatory basin, and sink, with 2,000 sq. ft. of roof and paved surfaces discharging water into the sewage drain.

Here the volume of sewage, ignoring faecal matter, would represent on a six-hour working day approximately:

$$\frac{10 \times 40}{6 \times 60} = 1{\cdot}2 \text{ gallons per minute}$$

and the rainfall $= 2000 \times 0{\cdot}0347 = 69{\cdot}4$,, ,, ,,

a total of $70{\cdot}6$,, ,, ,,

a volume, according to Table No. XV (p. 300), which could be conveyed by a 4-in. drain running half full.

Example 2. A block building containing twelve tenements each fitted with a w.c., bath, and sink, and having an average of five occupants per tenement. The draining area for rain- and surface-water may be taken as 3,800 sq. ft.

In this case (again ignoring faecal matter):

the sewage $= \dfrac{12 \times 5 \times 40}{6 \times 60} = 6{\cdot}7$ gallons per minute

and the rainfall $= 3{,}800 \times 0{\cdot}347 = 131{\cdot}8$,, ,, ,,

a total of $138{\cdot}5$,, ,, ,,

a quantity that could be conveyed (as per Table No. XV) by a 4-in. drain running full.

In practice it is found that a 4-in. drain is adequate for the number of tenements fitted up as here quoted. Moreover, the rainfall provided for is so exceptional that under normal working conditions the drain would serve a larger number of tenements or dwellings than here specified.

For trade premises discharging large volumes of liquids it is essential to ascertain the maximum daily consumption of water, and to add the estimated rainfall.

Size of Soil- and Waste-pipes

Pipes 3 in. in diameter are sufficient for one to three water-closets or slop-sinks where, as in the case of certain siphonic closets, the trap outlet does not exceed 3 in.

The drawback of small-diameter pipes is the ease with which the air is exhausted or driven out as compared with pipes of larger diameter, resulting in the siphoning out of the contents of the connected traps.

A marked tendency to unsealing of the traps by momentum is especially pronounced in the case of small-diameter pipes connected to slop-sinks, and water-closets used for the reception of slops, owing to the rapidity with which the pail contents are discharged into the fitment. If 3-in. pipes are used the trap should be ventilated even where but one fitment is connected to the pipe, and the trap-ventilating pipe should preferably be not less than $2\frac{1}{2}$ in. in diameter.

The number of fitments which may properly be connected to $3\frac{1}{2}$- and 4-in. diameter pipes is frequently under-estimated, six and ten respectively being sometimes stated as the maximum.

The velocity of discharge through a vertical pipe is much greater than a drain pipe as given in Table No. XV, and that through the connected branches is at least equal to the figures quoted in the Table. Consequently the discharging power of a soil pipe of the same diameter as the drain to which it is connected is solely determined by the latter.

Many 2-gal. flushing cisterns discharge this nominal amount in four seconds—a rate of 0·5 gal. per second, or 30 gal. per minute. If this is assumed as the basis for calculation it follows that the number of fitments connected to a 4-in. pipe should be limited to four, which together discharge at the rate of 120 gal. per minute. Such an assumption, however, entirely overlooks the rarity with which fitments connecting with a single pipe

discharge simultaneously, and observation shows that under many working conditions, with proper ventilation to the pipe and traps, as many as 25 water-closets will operate successfully when connected to a 4-in. pipe, and 17 fitments when connected to a $3\frac{1}{2}$-in. pipe. A hard and fast rule is not justified as local circumstances and use have to be taken into consideration, but it is safe to assume, with efficient ventilation, the successful operation respectively of 20 and 14 water-closets connected to pipes of the diameters mentioned.

Tests made by the author on $3\frac{1}{2}$-in. vertical waste pipes with five $1\frac{1}{2}$-in. and five 2-in. branch pipes respectively from baths and sinks have conclusively shown that six of the fitments—3 baths and 3 sinks—could be simultaneously and effectively discharged; and as under normal working conditions it would indeed be seldom for this number to discharge at one and the same time, it may be concluded that a main waste pipe of the stated diameter is sufficient for more than ten fitments of the character named.

XVII

SOIL FITMENTS: WATER-CLOSETS

IN the definition[1] of a 'sanitary convenience' are included urinals, water-closets, earth-closets, privies, and any similar convenience; a form of words embracing a slop-closet, slop-sink, urinette, or any other form of fitment for the reception of faecal matter, in addition to those specifically named. In quoting the statutory powers a clear distinction must be drawn between the use, on the one hand, of the inclusive and comprehensive terms 'sanitary convenience' and 'sanitary accommodation' and, on the other hand, references to specific fitments—such as water-closets.

Provision of Sanitary Conveniences[2]

In London the sanitary authority can (1) provide and maintain *sanitary conveniences* for public accommodation, other than privies, and (2) sanction (in writing) the erection of public sanitary conveniences (by which is apparently meant conveniences available to the public—such as those provided in connexion with licensed refreshment houses) in or accessible from any street.[3]

Sufficient and separate water-closets are required for every house;[4] but where a water-closet has been in continuous use by the inmates of two or more houses since 1891 and the sanitary authority are satisfied with such provision they need not insist upon a separate convenience.

In urban districts[5] the local authority may provide sanitary conveniences for public accommodation,[6] and

[1] Public Health Acts Amendment Act, 1890, and Public Health (London) Act, 1891.

[2] See also Chapters VII, VIII, IX, and X.

[3] Public Health (London) Act, 1891. Such conveniences must be so placed or constructed as not to be a nuisance or offend public decency, *vide* London County Council (General Powers) Act, 1904.

[4] Public Health (London) Act, 1891. This expression includes schools, also factories and other buildings in which persons are employed.

[5] Urban powers may be conferred on rural districts by a general Order of the Minister of Health.

[6] Public Health Act, 1875.

permit the erection of public sanitary conveniences in or accessible from any street.[1] Separate water-closet accommodation can be required for every house, but an existing convenience used in common may continue in use with the approval of the authority.

Generally, the sanitary authority is empowered[2] to make and enforce by-laws for (*a*) the construction of water-closets, earth-closets, and privies and their maintenance in proper order, and (*b*) the keeping of water-closets provided with sufficient water. The public health Acts[3] provide for the examination of such conveniences, cleansing, amending, and altering those in bad condition, and preventing improper construction, repair, injury, fouling, or nuisance.

Sufficiency and Form of Accommodation

'Sufficient', 'proper and sufficient', 'sufficient and suitable' are the expressions most used in the legal stipulations requiring the provision of sanitary conveniences. For premises having specified uses a standard, either definite or approximate, is laid down by the controlling authorities, as set out in Chapters VII, VIII, IX, and X.

For existing houses outside London the local authority can determine the number to be provided subject to an appeal to the Minister of Health; but for new or rebuilt houses the decision in the event of dispute rests with a court of summary jurisdiction.[4] In London the decision in all cases is in the hands of the sanitary authority subject to an appeal to the county council.[5]

[1] Public Health Act, 1890. The local authority can also order the removal of a urinal or other sanitary convenience opening on any street if so placed or constructed as to be a nuisance or offend public decency. Public Health Acts Amendment Act, 1907.

[2] Public Health Acts, 1875 and 1890, and Public Health (London) Act, 1891. In London (other than the City) the by-laws relating to the construction and maintenance of water-closets, &c., are made by the county council and enforced by the borough councils. By-laws with regard to water-supply are made and enforced by the borough councils.

[3] The Public Health Acts, 1875 and 1890, and Public Health (London) Act, 1891.

[4] Public Health Acts, 1875 and 1890.

[5] Public Health (London) Act, 1891.

In London[1] the form of convenience required is a water-closet, but it is provided that where sewerage or water-supply is not reasonably available the requirement shall be complied with by the provision of a privy or earth-closet. The availability of sewerage is determined by the existence of a sewer within one hundred feet of the building (see Chapter XXI, p. 364).

Outside London the convenience may be in the form of a water-closet, earth-closet, or privy. Where, however, the Public Health Acts Amendment Act, 1907, has been adopted and a sewer and sufficient water-supply are available, water-closets or slop-closets can be insisted upon by the sanitary authority for either new or existing buildings. The sanitary authority are likewise empowered by this Act to order (under specific conditions) the conversion of a privy or an earth-closet into a water-closet or slop-closet.

Water-closets

Whatever the type of convenience permissible, water-closets are the best form and should always be provided where a water-supply and a water-carriage system of sewerage are available.

From the period when originally installed such fitments have assumed various forms, of which some are now obsolete and unacceptable, while others survive in an amended and improved form. In the first category may be placed pan or container, trapless, short- and long-hopper, and wash-out closets, the defects of which are too well known to need explanation, it being sufficient to say that they do not fall within the definition of a suitable fitment as given in many operative by-laws.

Taking public health by-laws as indicating a criterion of fitness, in London[2] a water-closet fitment must be in the form of a suitable soil-pan or basin, of non-absorbent

[1] See footnote 5, p. 305.

[2] By-laws made by the London County Council under section 39 (1) of the Public Health (London) Act, 1891.

material, fitted with a flushing rim, and of such shape, capacity, and mode of construction as to receive and contain a sufficient quantity of water, and to allow all filth which may be deposited in such soil-pan or basin to fall free of the sides thereof and directly into the water contained in such soil-pan or basin.

The Model code[1] stipulates 'a pan, basin, or other suitable receptacle of non-absorbent material so constructed and fitted as to receive and contain a sufficient quantity of water and to allow any filth to fall free of the sides and directly into the water'; and the 'Model Specification of Water Pipes and Fittings (1926)' issued by the Minister of Health prescribes that 'the pan or basin . . . should be constructed as to be effectively cleared by one discharge of the flushing apparatus'.

Materials

The most suitable materials for pans or basins are enamelled earthenware, and vitreous china or porcelain Salt-glazed stoneware is strong but not equal in finish to the foregoing. Cast-iron fitments (painted, galvanized, vitreous- or porcelain-enamelled) are, at their best, inferior to the other materials. Pans and traps may be in one piece, or the pan and trap may be separate, in which case a ware, iron, or lead trap may be used. Iron traps should be vitreous- or porcelain-enamelled inside and enamelled or bituminous-coated outside.

Types

The present-day selection of a suitable fitment is for all practical purposes restricted to three types, viz., siphonic, wash-down, and valve closets.

Siphonic closets are increasing in favour and use, a circumstance due to the dependence which can be placed upon the certain removal of the entire contents of the basin and trap and their replacement by the clean water

[1] Urban, Series IV, 1925.

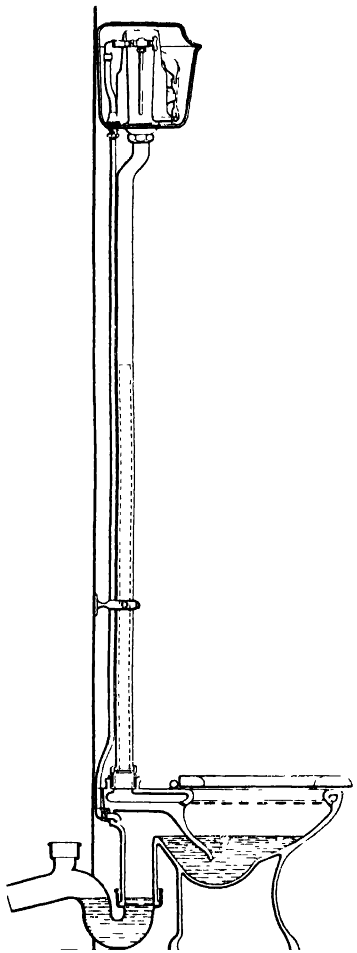


Fig. 183. Shanks's 'Venetian' siphonic closet with overhead cistern.

used for flushing, and this with the limited quantity of water allowed by the water authorities for flushing purposes. Such closets are operated on the principle of rarefying the air in the soil- or drain-pipe close to the trap sufficient to reduce the atmospheric pressure on the surface of the water in the discharging side of the trap below the normal, thus permitting the atmospheric pressure on the surface of the water in the basin to push out the contents of the basin and trap into the soil pipe or drain.

The air rarefaction to effect this is mostly secured in one of two ways: (1) the provision of a second trap below the ordinary trap attached directly to the basin so as to provide a restricted length of pipe from which the air can be forced out by a jet or spray of water and discharged to the outer air through a vent, or exhausted by means of a small-diameter pipe carried up from the confined leg between the traps and connected to the flushing cistern in such a way that on a discharge from the latter the air in the confined leg is 'dragged' out through the air pipe, thereby reducing the atmospheric pressure on the surface of the water on the outlet side of the trap or seal, as in

Fig. 183; or (2) the formation of the outlet pipe from the trap in such a manner as to permit the water flushed through the trap driving the air in front of it. Fig. 184 illustrates a simple contrivance for effecting this, consisting merely of a bulbous enlargement of the pipe which allows the water to travel down the inner surface of the bulb and its direction towards the centre of the pipe, from which it pushes out sufficient air to allow the siphonic action to be set up.

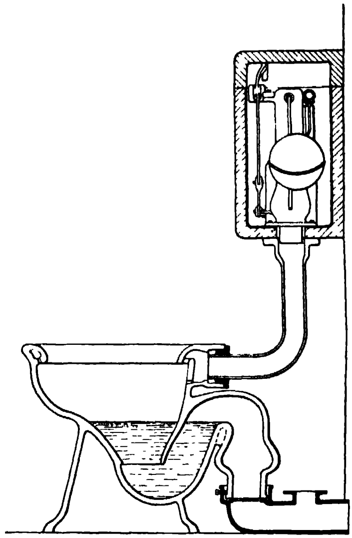


FIG. 184. Shanks's 'Albany' siphonic closet with low-down cistern.

By the methods employed in Figs. 183 and 184 the whole of the water in the flushing tank is utilized for clearing and cleansing the basin and trap, a considerable advantage when the volume of water available is restricted to two gallons per flush. A large water area can be provided for in all basins, but an after-flush is necessary to ensure full recharging of the basin. In certain forms the trap outlet is reduced in size to a diameter as small as $2\frac{1}{2}$ in. without interfering with the discharge of the solid matters.

Wash-down closets show extensive variations in detail, but good types should all conform to the by-law standard. If the pan is separate from the trap this allows for connexion to soil-pipe or drain at varying angles. So fitted the joint between pan and trap should be below the water-level so as to disclose any defect. For general use the pedestal type in one piece of ware is preferable as it is stronger, can be more securely fixed, and has one joint less.

Innumerable patterns are available, with but little diver-

sity in design but notable distinctions in the strength and serviceableness of the ware and the quality of the enamel. The fitment illustrated by Fig. 185 is of the usual type and is suited for ordinary use; while Fig. 186 is a 'projector' or corbel closet particularly serviceable for hospitals and other institutions where the greatest possible cleanliness of fitment and surroundings is the *sine qua non*.

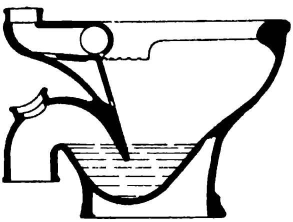


FIG. 185. Wash-down closet.

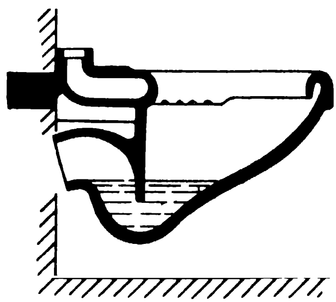


FIG. 186. 'Projector' or 'Corbel' closet.

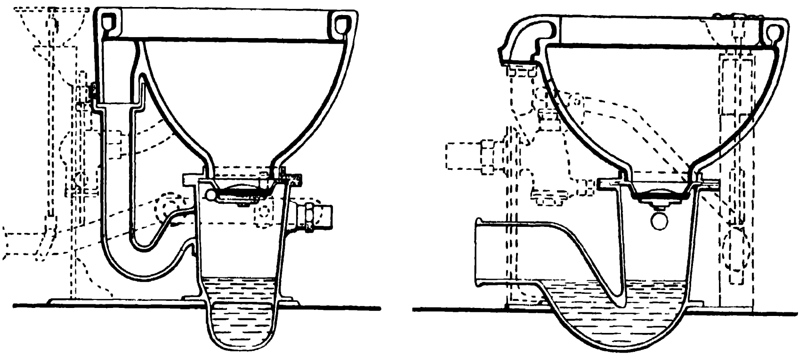
Other special fitments are designed to obviate contagion from persons suffering from venereal disease; for prisons, mental hospitals, and schools; the last-mentioned including a dwarf or 'low' closet for infants, having a height of about 11 in., instead of the normal height of 16–18 in.

Valve closets.—With the older pattern the trap was often below the floor-line. The best modern patterns have, as in Fig. 187, an above-floor trap with a visible and satisfactory connexion to the soil-pipe. Care should be taken to ventilate the valve box so as to secure a change of air and prevent siphonage of the trapped overflow pipe. Where intended for men's use or to receive slop-water a pedestal pattern with top, sides, and bow-shaped front in glazed white-ware should be selected, the size of such enclosure being limited to that needed for encasing the fitment.

It must be admitted that there are more hidden parts liable to fouling than in the siphonic and wash-down types, and if in the form of an enclosed fitment it is less

suitable for use as a urinal. Further, such advantages as the type possess, are also met by the siphonic fitment.

Trough closets or latrines, though not specifically classi-



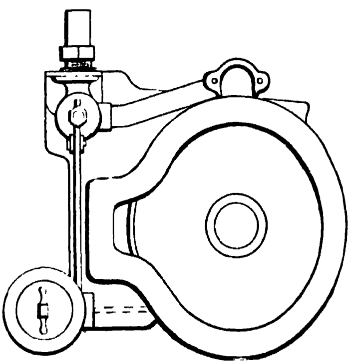


FIG. 187. Shanks's valve closet with trap above floor.

fied as water-closets, fall within such category inasmuch as water is the means of operation. Extensively installed years ago for grouped fitments in schools, factories, and other places where a number of persons were engaged, their installation was, and still is, justified by some persons on the ground that the fitment can be used effectively where an ordinary type water-closet would be of little service owing to liability of stoppage. A further alleged justification is the smaller amount of water needed for their operation than is required for the proper working of individual closet-basins.

It is true that trough closets are less easily stopped up than the single basin and trap, and equally true that but a small quantity of water is compulsory, for the volume used entirely depends upon how often the fitment is flushed. The point of comparison, however, is fitness as

a sanitary appliance, and on this the trough is vastly inferior. A water-closet is expected to have the qualifications set out above (p. 306); a trough does not comply and therefore is not in conformity with such by-law requirements. Moreover it possesses a large fouling surface difficult to flush and maintain in a clean state; faecal matter is deposited often in a quantity of water insufficient to cover the solids; and the prompt removal (by which may be understood flushing and cleansing after each user) aimed at in the case of a water-closet is not brought about. Furthermore, use of a particular section of the trough causes effluvium nuisance in other sections and to other users, added to which is the risk of dried particles of infective matter being disseminated from the uncovered stools of persons suffering from disease.

In type, troughs range from a rectangular brick or concrete channel, flushed either by hand or by a discharge from a cistern, through various patterns in plain or enamelled iron, salt-glazed stoneware, and enamelled fire-clay, to fitments with isolated basins operated siphonically in conjunction with an automatic flushing cistern. The isolated type is an improvement on the former, inasmuch as the open trough is superseded by a pipe of smaller perimeter filled with water. Infrequent flushing, however, allows for the accumulation of solid and liquid faecal matter in the basins and pipe with all the attendant objections. The removal of faecal matter immediately after deposit must be considered the paramount necessity with all soil fitments.

Waste-water closets, by which is understood fitments designed for the reception of faecal matter with the utilization of waste water as the flushing medium, are as illustrated by Fig. 188, fitted with a 'tipper' for periodic discharge, or so arranged that the waste water discharges direct into trap. Such fitments are accepted in some districts where the water-supply available for flushing is restricted, and in many other districts where such reason

cannot justifiably be urged. In areas where the Public Health Acts Amendment Act, 1907, is in force the Minister of Health may permit the use of slop-closets if satisfied that the circumstances are such as to warrant this form of accommodation as being necessary or expedient.

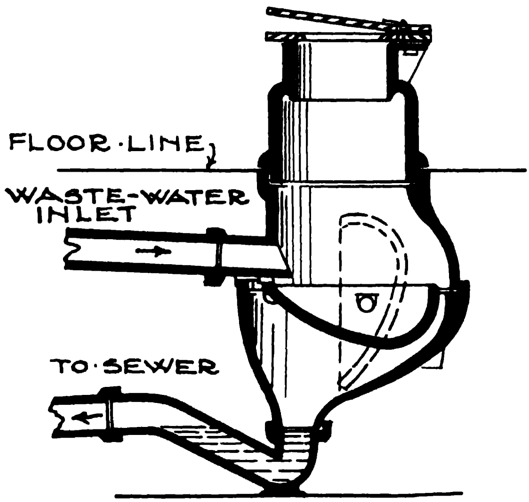


FIG. 188. Waste-water closet with automatic tipper.

Sanitarily, little can be said in favour of the type. The interior of the fitment, trap, and connected pipes is fouled by greasy water, or faecal matter, or both, the flushing is intermittent and nuisance is hardly avoidable. In many circumstances it is better to get rid of the waste water direct to the drain and to fit up a properly equipped earth-closet for the reception of faecal matter.

'*Eastern*' or '*Native*' *closets*.—For Indian and other eastern peoples whose social usages regard unfavourably the use of a seat during defecation special fitments are needed. In communities where a water-carriage system of drainage is non-existent the sanitary convenience often takes the form of a trench latrine, i.e. a trench about 12 in. deep and 18 in. wide, or a well or midden privy merely consisting of a hole 5 to 20 ft. deep dug in the soil; the

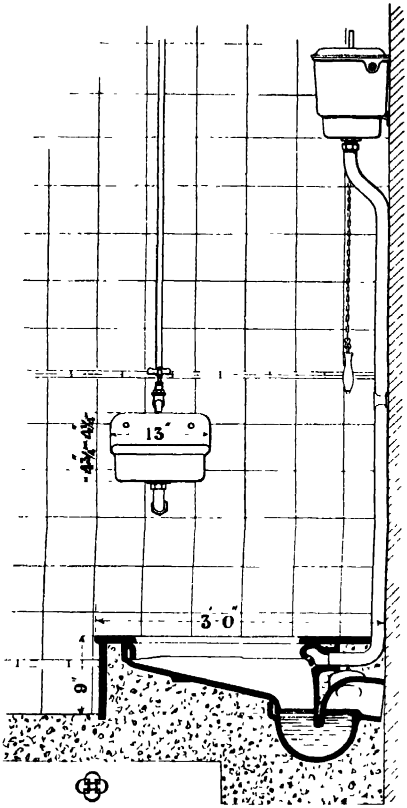


FIG. 189. Doulton's 'Hindostan' closet with flushing cistern and ablution sink.

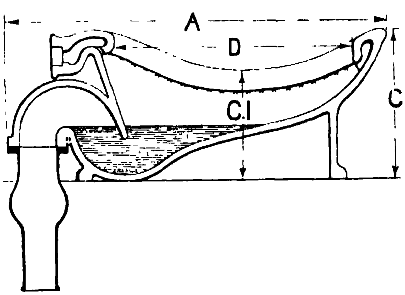


FIG. 190. Shanks's 'Vitrosan' eastern pedestal siphonic closet.

well or trench being used until full and then covered with earth and a new one prepared; or a fixed or permanent latrine or service privy suitably constructed and used with pail receptacles for faeces and separate receptacles or vessels for urine and wash-water.

Where advantage can be taken of a water-carriage system a much improved type of fitment and arrangement is practicable. To allow for a 'squatting' position a low-down pattern or one finished level with the floor is essential, so designed as to prevent splashing during use. Fig. 189 illustrates for good-class work a single closet set complete with Vulcanware or Queensware pan and trap, 3-gallon water waste preventer, marble squatting plate, and white-glazed ablution sink. An alternative to a floor-level fitment is the pedestal siphonic closet given in Fig. 190, made in vitreous china with cast-iron outlet for connexion to drain, the

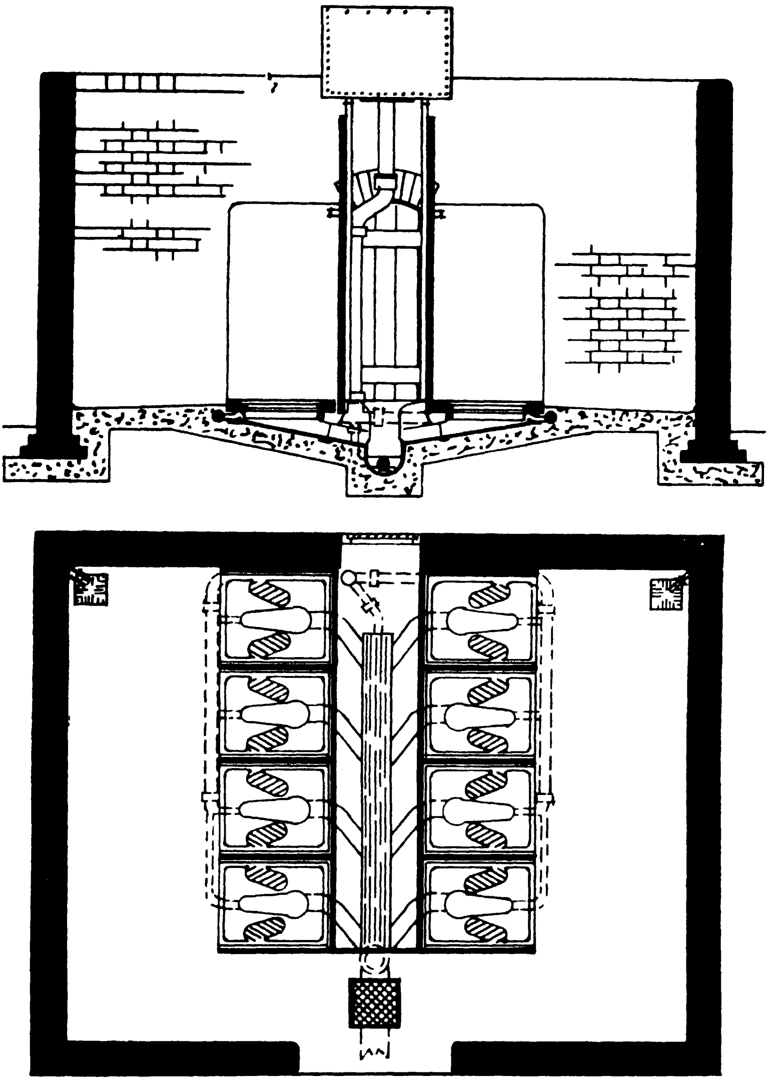
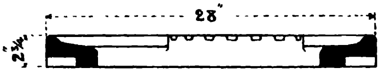


FIG. 191. Doulton's 'Eastern Closet' range with automatic flushing cistern.

concave top of which permits the user to be close to the basin without actual contact and avoids fouling the surroundings. The height can be reduced by sinking

the closet slightly into the floor or by raised foot-treads on floor. Fig. 191 illustrates a range of fitments comprising Vulcanware cane or white-glazed squatting plates, white-glazed closet pans, and three-quarter section open channel bends, 9-in. stoneware centre channel with flushing inlet and weired outlet, 6-in. P trap with inspection socket, galvanized iron airtight manhole cover with 12 in. × 12 in. opening, galvanized W.I. automatic tank, special regulating valve, cast-iron down-pipe and branches to centre channel and flushing inlets of pans, and marble divisions, end slabs, and back partitions; Fig. 192 shows a squatting plate with raised foot-treads for a closet or urinal for fixing on floor over basin, and Fig. 193 a urinal squatting plate discharging into an ordinary half-round channel leading to a drain inlet. As water is used instead of paper for cleansing purposes the provision of a draw-off tap over a sink or drain inlet is imperative.



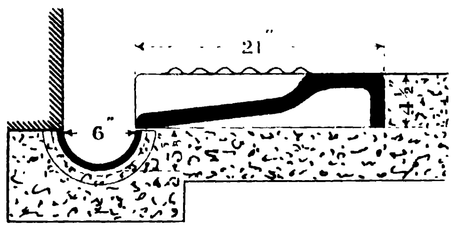


FIG. 192 (*above*). Doulton's 'Penang' squatting plate for closet or urinal.

FIG. 193 (*below*). Doulton's 'Madras' urinal squatting plate discharging into channel.

Fitments of this character are extremely useful for many person of divers nationalities other than those belonging to a caste for whom the type is specially designed.

Flushing of Water-closets

The by-laws in London[1] require for the flushing of water-closets a suitable cistern separate and distinct from any drinking-water cistern, and without any direct connexion between any water-service pipe and any part of

[1] See footnote on p. 210.

the closet basin; a suitable apparatus in such cistern for the effectual application of the water to, and cleansing of, the basin; and a flush-pipe of lead, iron, or other equally suitable material between the cistern and the flushing arm of the basin not less than $1\frac{1}{4}$ in. in internal diameter.

The Model by-laws[1] specify 'a separate cistern or flushing box of adequate capacity'; that 'no part of the water-closet apparatus other than the cistern or flushing box shall be directly connected with any service pipe'; and the provision of a 'suitable apparatus for the effectual application of the water in the cistern or flushing box to the pan and for the prompt and effectual flushing and cleansing of the pan'. In fitting flush-pipes 'easy' bends are necessary to prevent a reduction in the velocity of the discharging water, and a suitable connexion between flush-pipe and flushing arm of basin.

Model by-laws issued by the Minister of Health[2] for preventing misuse, contamination, &c., of water stipulate, *inter alia*, that 'No pipe other than a flushing pipe leading from a proper flushing apparatus shall deliver water to the pan of any water-closet or to any urinal'. To meet this requirement every water-closet and urinal must have a flushing cistern or be supplied from one that is distinct from that supplying drinking-water.

The by-laws also provide:

(1) Every water-closet and urinal shall be provided with a proper flushing cistern or with some other equally suitable and efficient apparatus for the proper flushing of the water-closet or urinal.

(2) Every cast-iron flushing cistern shall be not less than *three-sixteenths of an inch* thick, with a bead round the top.

(3) Every flushing cistern shall have an efficient waste-preventing apparatus of the valveless type.

Provided that this requirement shall not apply to any flushing cistern in any hospital, lunatic asylum, institution for mental defectives, sanatorium, workhouse, or public elementary

[1] See footnote on p. 307.

[2] By-laws for preventing the waste, undue consumption, misuse, or contamination of water: Model By-laws, Series XXI, 1926.

school, if the water is supplied by measure to such hospital, lunatic asylum, institution, sanatorium, workhouse, or school, and if all practicable steps are taken in the construction of such cistern to prevent waste, undue consumption, misuse, or contamination of water.

(4) The siphon (or dome and discharge-pipe as the case may be) of every flushing cistern shall either be of corrosion-resisting materials or be efficiently protected against corrosion.

(5) The ball-tap of every flushing cistern shall be of such design as to allow the cistern to fill rapidly and shall close when the water rises to the water-line.

(6) If the flushing cistern be of a capacity not less than *two gallons*, the outlet nipple, the tail-pipe, and the flush-pipe shall each be not less than *one inch and a quarter* in internal diameter.

(7) A flushing apparatus provided in connexion with a water-closet shall be capable of giving a flush of not less than *gallons* nor more than [1] *gallons* of water.

(8) A flushing apparatus operated by hand and provided in connexion with a urinal or group of urinals shall be capable of delivering a flush of not less than *one gallon* nor more than *gallons* to such urinal or to each urinal in such group.

(9) A flushing cistern provided in connexion with a water-closet or urinal shall be so constructed and maintained that water cannot flow down the flushing pipe except whilst a flush is being properly delivered, and so that it shall not discharge at one flush more than its nominal capacity.

The by-laws specify the minimum weight per lineal yard of lead flushing and warning pipes as follows:

TABLE NO. XVI. *Minimum weights per lineal yard of lead flushing and warning pipes prescribed in the Model By-laws.*

Bore not exceeding . .	$\frac{3}{4}$ in.	1 in.	$1\frac{1}{4}$ in.	$1\frac{1}{2}$ in.	2 in.
Weight (in lb.) . . .	5	7	9	11	14

Copper and brass pipes should be seamless drawn and of the following minimum weight and thickness:

[1] If the figure here is less than *three gallons* a proviso should be inserted by the Water Authority on the lines of that in clause (3).

TABLE No. XVII. *Approximate minimum weight and thickness of metal for copper and brass flushing and warning pipes.*

Bore not exceeding		½ in.	¾ in.	1 in.	1¼ in.	1½ in.	1¾ in.	2 in.
				Copper.				
Thickness of pipe wall	I.S.W.G.	19	19	18	18	18	17	17
	Decimals of an inch.	0·040	0·040	0·048	0·048	0·048	0·056	0·056
Weight per lineal foot (in lb.)		0·26	0·38	0·61	0·75	0·90	1·22	1·39
				Brass. (Containing 70 per cent. of copper.)				
Thickness of pipe wall	I.S.W.G.	18	18	17	17	17	16	16
	Decimals of an inch.	0·048	0·048	0·056	0·056	0·056	0·064	0·064
Weight per lineal foot (in lb.)		0·25	0·39	0·62	0·78	0·94	1·26	1·44

In addition to the Model by-laws the Minister of Health has issued a 'Model Specification of Water Pipes and Fittings'[1] which embodies the following:

Flushing Cisterns

(i) Every lead-lined and copper-lined flushing cistern should comply with the requirements[2] for lead-lined and copper-lined storage and feed cisterns, except that for a cistern of not exceeding 3 gallons capacity (*a*) the wood may be finished not less than ¾ in. thick and (*b*) if lead-lined, the lead-lining might be of not less weight than 4 lb. per superficial foot.

(ii) Every cast-iron cistern should be not less than $\frac{3}{16}$ in. thick, with a bead round the top, and should be efficiently protected against corrosion.

[1] 1926.

[2] These requirements are: 'The wood used for cisterns, lined with lead or copper should be well-seasoned and free from sap, finished not less than 1 in. thick; the lead should be of not less weight than 5 lb. per superficial foot, and the copper should be of not less than 22 I.S.W.G. The joints in a lead-lined cistern should be burned or wiped soldered joints, and the lead should be turned over the top edge of the cistern. The joints of a copper-lined cistern should be welted and brazed.'

(iii) Every wrought-iron cistern should be made from sheets of a thickness of not less than 16 I.S.W.G., and should be efficiently protected against corrosion.[1]

(iv) Every 'earthenware', 'fire-clay', or 'stoneware' cistern should be not less than ½ in. thick.

(v) (See (3), p. 317.)

(vi) The cistern should be longer and wider at the top than at the bottom, and, in the case of cast or moulded cisterns, the corners should be rounded inside and outside.

(vii) The underside of the bend in the siphon pipe (or, in the dome pattern, the top of the straight discharge-pipe) should be not less than ⅛ in. above the top of the cistern.

(viii) (See (4), p. 318.)

(ix) The water-line should be plainly indicated on the inside of the cistern 1 in. below the lip or invert of the warning pipe at its inlet end.

(x) (See (5), p. 318.)

(xi) The cistern should be provided with a suitable tail-pipe of corrosion-resisting alloy, with a cap and back-nut screwed to fit the outlet nipple.

(xii) (See (6), p. 318.)

(xiii) The siphonic apparatus should be capable of being rapidly brought into action when the water is at the water-line, and should be so constructed that water cannot flow down the flush-pipe except whilst a flush is being properly delivered, nor any siphonic discharge take place until the cistern has filled up to at least 75 per cent. of its nominal capacity.

(xiv) The cistern should be capable of discharging at the rate of two gallons in five seconds when attached to a flush-pipe.

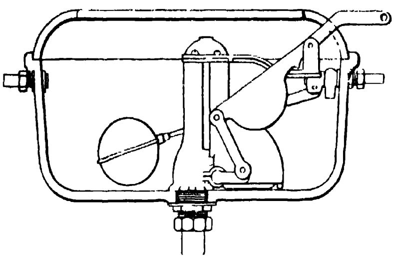
(xv) The cistern should not be capable of discharging at one flush more than its nominal capacity.

(xvi) The cistern should be so designed that there will be no appreciable decrease in the force of the flush during the discharge of the required quantity of water.

Flushing cisterns are made of cast-iron, sheet steel, glazed earthenware, enamelled fire-clay, marble, glass, and wood casings lined with lead or copper.

[1] Requirement for storage and feed cisterns; should be adopted for flushing cisterns.

As mentioned in the by-laws above quoted, the siphon or dome or discharge-pipe must be made of corrosion-resisting material or efficiently protected against corrosion —a requirement met by using brass, lead, or copper, or galvanized or glass-enamelled iron. It is desirable that the cistern as a whole should conform to this requirement.



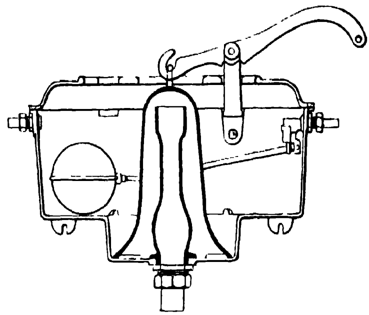


FIG. (*left*) 194. Shanks's 'Rotunda' valveless flushing cistern.
FIG. (*right*) 195 Shanks's 'Levern' valveless flushing cistern.

The mode of fixing is by lugs, forming part of the casting, screwed to the wall or to a back-plate secured to the latter, cantilevers, or wall brackets.

The by-laws specify 'an efficient waste-preventing apparatus of the valveless type', except in elementary schools and the other places named in proviso (3) (p. 317), where valve cisterns are permissible if the supply is by meter and attention is given to the stated conditions.

Valveless cisterns vary much in detail. In some the siphonic action is started by the upward or side manipulation of a disk which forces a quantity of water over the siphon bend into the flush pipe (i.e. the long leg of the siphon), thus driving the air out and permitting the normal atmospheric pressure on the surface of the water in the cistern to push out the contents; while with others a quantity of water is similarly precipitated over the siphon bend by the lifting, or letting fall, of a dome. Figs. 194 and 195 illustrate typical fittings.

Capacity of Cistern

The discharging capacity of cisterns is commonly limited by the water authority to two gallons; but some allow three gallons. Where the supply is controlled by meter the practice varies, in some districts two gallons is the limit, in others three, while in others the quantity is not restricted. Public health by-laws seldom specify the quantity, the expression used being 'a cistern of adequate capacity'. Wherever allowable three gallons should be provided for.

The supply valve should allow for charging of the cistern within $1\frac{1}{2}$ minutes. If required to prevent noise a silencer should be fitted. With regard to the latter it is essential that 'means shall be taken to prevent the siphonage of water back into the supply pipe'[1] from any silencing pipe carried below the outlet to the overflow pipe. An overflow is necessary, and this must take the form of 'an efficient warning pipe'.[1]

Position of Cistern

The usual type of cistern should be fixed at a height of at least 5 ft. above the pan. Low-down cisterns (Fig. 184) are now being used in increasing numbers as they minimize the noisy flushing action almost inseparable from those fixed at a high level, the loss of head being made good by increasing the internal diameter of the flush-pipe to 2 in. or thereabouts. In prisons, cisterns are commonly fixed outside the cell. In both mental hospitals and prisons, if fixed in a position available to the inmates, the cistern and all connected pipes and fittings must be of such design or so encased as to prevent misuse.

Operation of Flush

Normally a 'pull' in chain or rod form is used. Low-down cisterns can easily be manipulated by a small press-

[1] Model By-laws, Series XXI. See footnote 2 on p. 317.

down lever. For mental hospitals and prisons a 'push' valve is sometimes preferred, worked by direct-water agency, or pneumatically, in either case the action being to force a jet of water over the top of the siphon and into the long leg sufficient to drive out the air and start the flush.

To prevent misuse in schools and institutions a chain 'pull' should be enclosed in a metal tube, or a rod slide utilized.

Flushing Valves

Valve closets are flushed by means of an underseat valve, which, as mentioned on p. 317, must be supplied from a storage cistern not used for drinking-water. To meet the requirements of the water authorities the valve must be of a waste-preventing kind, and to ensure recharging of the basin an after-flush device is desirable.

Valves of this pattern are now fitted to siphonic and wash-down fitments. They have met with great favour in America but in this country their adoption is not favourably looked upon by some water authorities. The valves are of two patterns, one giving an unlimited supply and the other regulated to a maximum discharge, including that needed for an after-flush. The Model by-laws[1] provide in place of a flushing cistern for the use of 'some equally suitable and efficient apparatus', and the objection to the 'regulated' pattern is therefore difficult to understand except from the view-point that the valve can be operated without the delay appertaining to the filling of a flushing cistern and thus possibly result in the use of more water. These valves give very satisfactory results, are quiet in action, and are especially suitable for adoption where the appearance of a fitment is a factor not to be ignored.

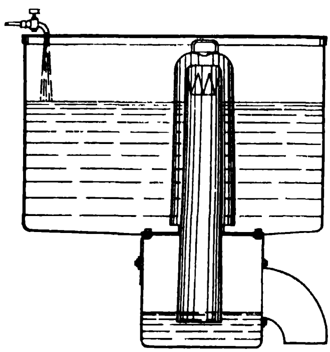
Flushing of Trough Closets

A flushing cistern operated by hand is sometimes used for trough closets, but the method is inefficient. Most

[1] Model By-laws, Series XXI. See footnote 2 on p. 317.

often periodic flushing is resorted to by means of an automatically operated discharge from a cistern, the capacity of the latter and the periodicity of discharge varying according to the assumed or proved necessity.

Automatic cisterns are of many kinds, but the siphonic arrangement is commonly of the annular pattern (Figs.



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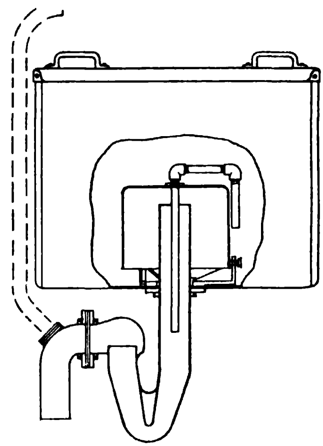

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FIG. 196. Stone's patent self-acting flushing cistern operated with a drop-by-drop supply. FIG. 197. Burns's 'Certus' automatic flushing cistern.

196 and 197), the supply being through a petcock alone or conjoined with a reverse-action ball-valve brought into play on a rise of the water-level in the cistern, or a 'tipper' fitting for filling the cistern and eventually discharging sufficient water over the siphon bend to start the action.

The capacity of the cistern should be determined by the number of seats or divisions. In principle it is better to have a relatively small and frequent discharge than the use of a large body of water at infrequent intervals. As a basis for calculation 5 gal. of water per seat may be accepted.

Seats and Enclosures

A fixed seat is undesirable. If a seat the full width of the apartment is wanted, either for women's use, or as

required in mental hospitals,[1] it should be hinged so as to afford access for cleansing around the fitment. Risers are not needed for pedestal fitments, and where provided in connexion with valve closets should be made so as to be entirely removable for access and cleansing and painted on the inner side with a hard white enamel. Seats are best fixed direct to pedestal fitment or to wall. Brackets are undesirable. To prevent absorption of moisture the wood should be French polished or enamelled. For water-closets used by men a balanced-action seat is advantageous as it facilitates the use of the fitment as a urinal.

For institutions, schools, factories, and similar premises seat insets made of teak or other hard wood or of vulcanite are cleaner and less likely to get out of order than hinged seats.

[1] *Suggestions and Instructions with reference to Sites, &c., of Mental Hospitals.* Commissioners in Lunacy.

XVIII

SOIL FITMENTS: EARTH-CLOSETS, PRIVIES, URINALS, AND SLOP-SINKS

Earth-closets and Privies

THERE is much ambiguity as to the proper interpretation of these expressions. An earth-closet may mean a convenience of any form in connexion with which earth is used for covering the deposited filth, and may range from a fixed receptacle where earth is spread by hand to one having a pail receptacle and a mechanical device for spreading the deodorizing covering. Similarly, a privy may be merely a depositing place for faecal matter in the form of a pit below, or an enclosure above, the ground-level without any pretence at covering with a deodorant; of the midden type where the house refuse is presumably used as a covering medium; or a fixed receptacle of limited size or a pail receptacle used with or without the application of a deodorizing substance.

A classification based on modern perceptions is:

(*a*) *Earth-closet*.—A convenience having a pail receptacle for filth and a receptacle for a deodorizing substance fitted with a mechanical device for distributing such substance over the deposited filth.

(*b*) *Privy*.—A convenience consisting either of a fixed or a movable receptacle for filth used without a deodorizing substance.

But little differentiation is expressed in the Model by-laws[1] between earth-closets and privies, the only apparent dissimilarity being the provision in the case of an earth-closet of a suitable vessel of adequate capacity for dry earth or other deodorizing substance so constructed and placed as to admit of ready access and fitted with means for the application of such substance to the deposited

[1] Urban, Series IV, 1925.

filth. Even this dissimilarity is not clear, for the by-laws also refer to privies identically fitted. The by-laws operating in London[1] are much more explicit and clearly differentiate between earth-closets and privies.

An earth-closet should be constructed for use with a movable receptacle for filth, and for this purpose provided with

(i) A hinged seat fitted with a urine guide.
(ii) A movable receptacle for filth of galvanized iron or other equally suitable material of a capacity not exceeding 2 cu. ft.
(iii) An underseat space of sufficient size to receive the filth receptacle and furnished with adequate means of access.
(iv) A suitably constructed receptacle for dry earth or other deodorizing substance with suitable means or apparatus for the application of such substance to the deposit in the filth receptacle.

A privy should be constructed for use with a movable receptacle for filth and comply with the suggestions set out in paragraphs (i), (ii), and (iii) above mentioned relating to earth-closets. With privies the retention of excreta for too long a period and the deposit of filth on exposed surfaces with the consequential evolution of noxious gases by fermentation and decomposition, the removal of the contents, and the disposal of the waste matters frequently cause effluvium nuisance. The construction and use of such conveniences should have no place in a community where either water-closets or earth-closets are possible. Where adoption is obligatory the pail type should be selected and a daily removal of the excreta assured.

In favourable circumstances[2] an earth-closet can be used without nuisance if close attention is paid to essential details. If unprovided with a suitable deodorant or neglect is shown in respect of removal of filth, it is no better than a privy, and hence a supply of the deodorizing substance

[1] By-laws made by the London County Council under Section 39 (1) of the Public Health (London) Act, 1891.
[2] See Chapter XXII, p. 400.

should be maintained[1] and the pail contents removed daily. As a deodorizer pure garden humus from the top layer or spit should be employed after storing and drying. (See Chapter XXII, p. 401.) If humus is not obtainable, 'living' soil possessing power of humification should be selected in preference to sterile and merely absorptive substances such as ashes, which fail to effect any humific change in the organic excreta. Corfield[2] placed the order of suitability of soils as (1) rich garden mould; (2) peaty soils; (3) black cotton soils; (4) clays; (5) stiff clayey loams; (6) red ferruginous loams; (7) sandy loams; and (8) sands.

The efficiency of an earth-closet depends largely upon the pail contents being kept dry: the convenience should not be used as a urinal nor for the reception of slop-water. Urinals and urinettes are advisable where earth-closets are provided in schools, factories, and other places frequented by many persons, with means of drainage or other suitable arrangements for the disposal of the liquid sewage.[3]

Fig. 85 illustrates an earth-closet with a salt-glazed fire-clay casing, a hinged hardwood seat, galvanized-iron earth and filth containers, the earth being applied by a lever-operated door or valve, and access to both containers given from outside the apartment by doors in the external wall; and, alternatively, the earth container fed from inside the apartment. In Fig. 86 is shown a privy casing in fire-clay with hinged hardwood seat, galvanized-iron bucket, and external access door. If preferred, a 'Dartmoor' tank can be used instead of a pail. (See Chapter XXII, p. 400, as to the disposal of excreta.)

Urinals

Where power is given to a sanitary authority to require a *sanitary convenience*, as instanced in Chapter XVII, p. 304, a urinal fitment can be stipulated. Accommodation

[1] The London by-laws (see footnote on p. 210) require the occupier of premises to at all times maintain a sufficient quantity of deodorizing substance.

[2] *Treatment and Utilization of Sewage*, pp. 99–100.

[3] See Chapter XXII.

of this kind is demanded in specific cases[1] and is recognized as essential in many circumstances where no legal compulsion is applicable as, for instance, in clubs, restaurants, offices, sports' grounds, and railway stations, on account of the greater fitness for the intended use than are water-closets.

The Public Health Acts of 1875, 1890, 1891, and 1907 include urinals as public necessaries which may be provided without charge to the users. The provision and maintenance of one or more proper and sufficient urinals in a proper position can be insisted upon at any inn, public-house, beer-house, eating-house, refreshment-house, or place of public entertainment.[2]

Urinals and Effluvium Nuisance

Few sanitary fitments at the present day disclose such extremes in type and sanitariness as urinals, the conveniences ranging from a crude and unprepared wall surface to fitments on which much thought and care have been expended in avoiding all details likely to favour the accumulation of dirt and prevent proper cleansing. Moreover, it is possibly no exaggeration to say that urinals, considered as a whole, are productive of more offence than water-closets, and this by avoidable reasons of unsuitable materials, bad construction, and inadequate flushing arrangements.

Urinals formed by a plain wall surface, or one coated with tar, rendered with cement or bitumen, or covered with sheet or plate iron (plain, galvanized, or enamelled), slate, marble, or stoneware, or constructed in stall fashion of these or similar materials with many filth-harbouring angles, or in basin or trough shape of unsuitable materials, with many co-relative defects and without means for effectually flushing, cannot reasonably be expected to be maintained free from effluvium nuisance.

[1] See Chapters VII, VIII, IX, and X.
[2] Public Health Act, 1907.

An appropriate specification[1] is:

'A urinal basin, stall, or trough shall be constructed of glazed earthenware, enamelled fire-clay, or other equally suitable material, of such shape as will facilitate maintenance in a state of cleanliness, and furnished with a suitable flushing cistern of a capacity equal to at least one gallon of water for each connected basin, or each width or length not exceeding two feet three inches of stall or trough respectively. Such cistern shall be separate and distinct from any cistern used for drinking-water, and be connected to such urinal by an adequate flush-pipe or pipes of lead, copper, iron, or other equally suitable material having a minimum internal diameter of half an inch and fitted with a suitable spreader or sparge-pipe so as effectually to distribute the water over the internal surface of each basin, stall, or trough.'

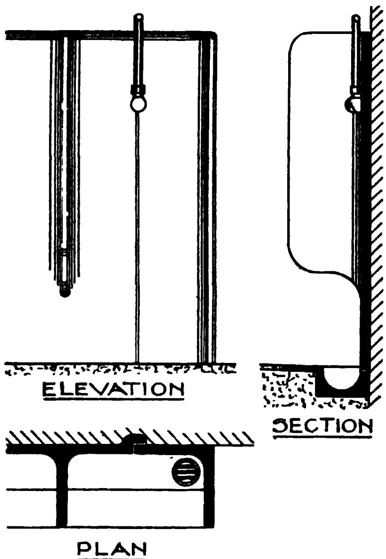

FIG. 198. Stall slab urinal with lapped joint in centre of stall and divisions with coved angles.

Materials

The selection of the most suitable materials may be limited, in order of merit, to enamelled fire-clay, glazed earthenware, glass, marble, slate, and vitreous or porcelain-enamelled iron. Of these the last is open to rejection owing to 'chipping' of the enamel. Slate is absorptive and consequently difficult to maintain in a clean state, a drawback applying, but to a lesser degree, to marble unless well polished; glass is easily fractured; and all have to be 'made up' to form the fitment, with the corollary of acute angles conducive to dirt accumulation.

[1] See footnote on p. 210.

Fire-clay and earthenware are now accepted as the materials best suited for securing the form and finish required to meet the present-day conception of a sanitary fitment.

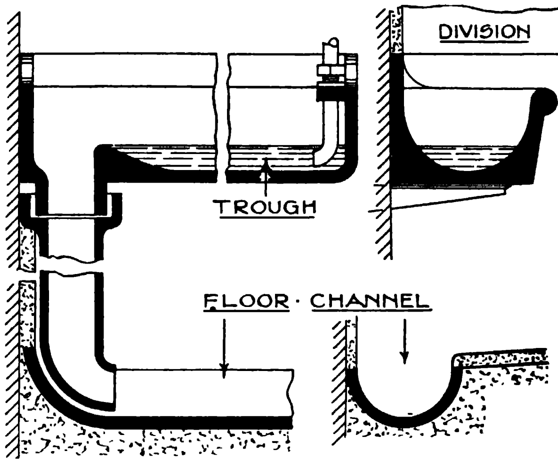

FIG. 199. Urinal trough with weir outlet, flush-pipe connexion, and waste pipe discharging into floor channel.

Design and Construction

The types[1] may be arbitrarily classified as slab, trough, basin, and stall fitments, each of which comprises bad and good examples.

Slab urinals are best formed of slabs with close-fitting plain or overlapped joints and a block channel. Fig. 198 illustrates a good pattern with lapped joints. This type is often selected for schools, factories, and other places where economy in cost and space are factors to be considered and where stress is not laid on personal privacy. Given adequate flushing the type of fitment shown can be maintained in a cleanly state with the minimum attention.

Trough urinals are of two types, i.e. a drain-away trough, and one (Fig .199) with a weir for the purpose of retaining the water in the trough, its removal being effected from

[1] For urinal 'squatting' plates see Chapter XVII, p. 316.

time to time by the discharge from the flushing tank or other method of flushing. In the use of the latter fitment much urine is retained in the trough and offence is thereby caused. A notable defect in these types is liability of fouling the wall space at the back of the fitment both above and below the trough, for which surface no flushing provision is made.

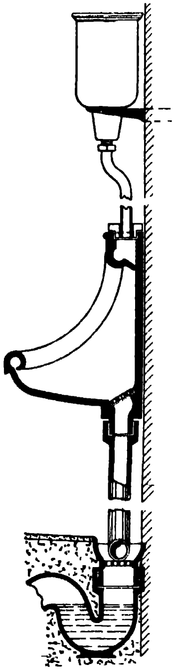

FIG. 200. Flat-back urinal basin with flushing rim, glazed-ware waste pipe, and flushing cistern.

Basin urinals can be had with round or lipped front and flat or angular back. A very real objection to the type is the necessity, when fixed in ranges, for suitable screens or divisions, and the fouling of the outside of basin and the surface of the walls and screens during use. Fig. 200 shows a flat-back basin with glazed ware down-pipe discharging over a trap, and glazed ware automatic tank. Where short waste-pipes are provided discharging into a channel they should be of glazed earthenware or enamelled fire-clay.

Stall urinals. 'Made-up' rectangular stalls afford many opportunities for the accumulation of dirt; the backs are often ineffectually flushed and the divisions commonly lack any pretence at flushing. Improved patterns are made with divisions shortened and limited in depth to that needed for screening.

The best type of urinal fitment for all positions is the circular- or radial-backed stall. The type if suitably designed is the *ne plus ultra*, as angles and corners allowing dirt accumulation are conspicuously absent and the maximum amount of exposed surface liable to fouling is brought under the control of the flushing agent. Many designs are available, from large and massive fitments with many embellishments to plain fitments just sufficient in size to be

effective: from a sanitary aspect no advantage can be claimed for the former. The most complete are those with the stall and channel in one piece with overlapped joints between the stalls.

Figs. 201 to 203 illustrate semicircular, radial-back or segmental stalls. For fixing singly in an angle, in pairs against a wall, or as an island fitment, these stalls may be adapted, or a special pattern obtained. The channels provided for stall urinals should, as in the illustrations, be situated in such a position as to render the use of foot-gratings—which are not easy to keep clean—unnecessary.

Flushing and Flushing Apparatus

A continual stream of water flowing over the used surface of the fitment prevents the accumulation of urine salts. Water-waste preventers are often fixed, but the practice is not a good one as persons using the convenience are habitually neglectful of the operation. For single fitments infrequently used a case can be made out for this mode of flushing, but it may be argued that where seldom needed it is better to utilize a water-closet fitment rather than provide a urinal.

An automatic flushing cistern should be regarded as indispensable. These are of many kinds and it is immaterial what particular form they take, the essential factor being a sufficient and definite discharge on a regulated time service. The quantity per flush ought not to be less than the minimum specified in the Model by-laws (Chapter XVII, p. 318) for a flushing apparatus operated by hand, i.e. one gallon per basin or stall or the equivalent slab space. Many water authorities regulate the frequency of the discharge from automatic cisterns by inserting, under seal, a disk in the service pipe.

The usual arrangement of flush-pipes to grouped fitments is to serve five or six stalls from one cistern. Taking a three-stall fitment and a supply of one gallon per stall,

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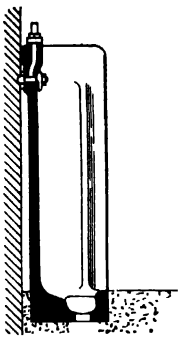

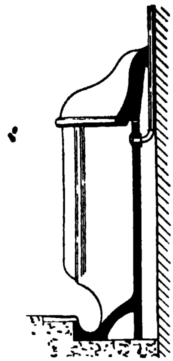

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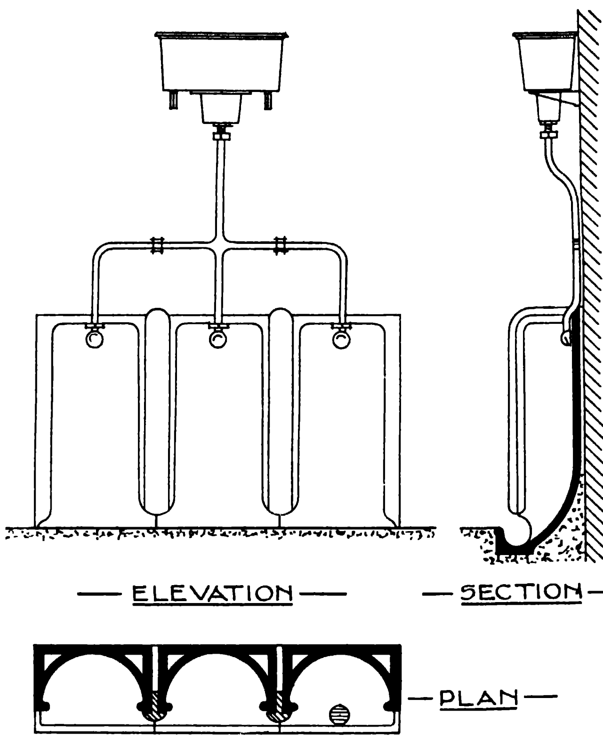


FIG. 201. Section of radial-back urinal stall and continuous channel in one piece with anti-splash rim and spreader.

FIG. 202. Section of circular-back urinal stall and continuous channel in one piece with shaped top, fire-clay tread and spreader.

FIG. 203. Plan, section, and elevation of circular-back stalls, with back and channel in one piece, flushing cistern, flush pipes, and spreaders.

a three-gallon cistern is necessary. For this capacity cistern the minimum internal diameter of the flush-pipe must be $1\frac{1}{4}$ in. (Chapter XVII, p. 318), a requirement definitely applicable to the main flush-pipe but which should not be construed as controlling the branch pipes to the con-

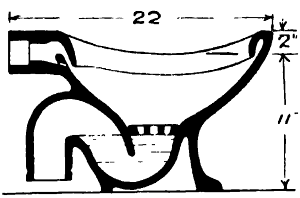


FIG. 204. Section of Adamsez urinette.

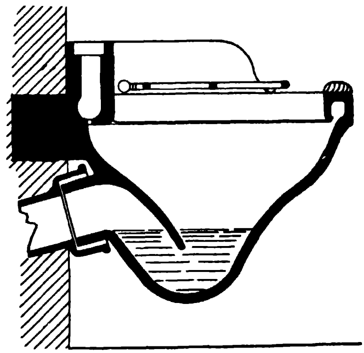


FIG. 205. 'Projector' slop sink with flushing rim, pad, and grid.

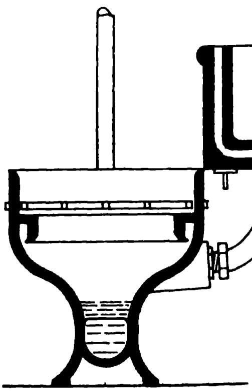
nected fitments.[1] The branch pipes should have a minimum internal diameter of $\frac{1}{2}$ in. (see p. 330).

Urinettes (Fig. 204) are the counterpart of urinals and are mostly provided for women's use in public lavatories. They are not in great demand but can conveniently be adopted where free use (i.e. without payment—as in the case of urinals) is desired, and in places where the water-supply is restricted to a flush of one gallon per basin. The materials used in the making and the form of the fitment are practically identical with wash-down water-closets except that the outlet is smaller—about 3 in. in diameter—and is fitted with a perforated grid which prevents the passage of solid matters. It is not customary to fix a seat. For flushing, individual cisterns of the waste-preventing type are often employed, but a range may be fitted up with an automatic flushing apparatus—a water-economizing method but one not favouring cleanliness.

See Chapter XVI, p. 298, for the relative discharging powers of pipes.

Slop-sinks

In large residences, hotels, hospitals, and other institutions special sinks are required for the reception of bedroom slops and the cleansing of utensils, purposes for which wash-up sinks are unfitted; the alternative to such



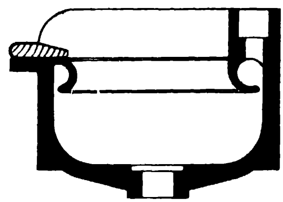


FIG. 206 (*left*). Shanks's combined slop and wash-up sink.
FIG. 207 (*right*). Small slop sink with flushing rim and wood pad.

provision being the use of water-closets for the waste matters and wash-up sinks for cleansing, with the concurrent probability of fouling of the fitments and drinking-water taps by faecal matter.

Conformity with the following specification[1] is suggested:

'A slop-sink shall be constructed of glazed earthenware, enamelled fire-clay, or other equally suitable material, of such shape, and furnished with such flushing rim, water-supply, and apparatus as to provide for the effectual flushing and cleansing of the slop-sink, and the trap and waste-pipe connected therewith.'

All slop-sinks should be made of white enamelled ware, with valves having an exterior finish of vitreous china or porcelain enamel.

For domestic use, i.e. dwelling-houses, hotels, residential schools and institutions other than hospitals and

[1] See footnote on p. 210.

infirmaries, a fitment of the kind illustrated by Fig. 205 is suitable, if provided with a flushing rim and cistern, a composition inset rim or pad to prevent breakage of crockery, a grid to receive a pail, and hot- and cold-water supply for cleansing utensils. Such a fitment may be combined with a housemaid's sink (Fig. 206). Where the need is a limited one the small porcelain slop-sink with flushing rim and wood pad shown in Fig. 207 may be used in conjunction with a flushing cistern and service valves.

In hospitals and infirmaries in addition to sinks for the disposal of slops provision for cleansing urine bottles and bed-pans is necessary, a typical fitment for which is shown in Fig. 208. If required, a sink for scalding macintoshes can form part of the fitment.

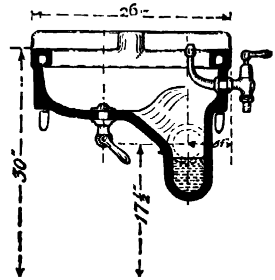


FIG. 208. Hospital slop sink with urine bottle and bed-pan jets (Leeds Fireclay Co., Ltd.).

The cleansing agent is commonly limited to cold water, for if hot water is used for urine bottles and bed-pans in open sinks offensive effluvium is liable to be dispersed. Hot water gives the best results, and therefore instead of an open sink an enclosed bed-pan and bottle flusher may be made use of, fitted with an air- and water-tight door, hot and cold supply valves, and a retaining valve which permits of the appliance being charged with disinfectant for steeping the bottles and pans.

To save soiling the fittings and to leave the hands free for the utensils foot and elbow devices of several kinds are employed.

XIX

ABLUTIONARY FITMENTS: BATHS, LAVATORY BASINS, AND BIDETS

THERE is not the same legal insistence upon the provision of ablutionary fitments as obtains in the case of sanitary conveniences, but, nevertheless, if hygienic circumstances are desired, such fitments must be regarded as indispensable. Of these fitments so many designs are obtainable that it must suffice to mention types selected on the ground of sanitary fitness, i.e. suitable materials coupled with a simplicity of design favouring efficient working and a high standard of cleanliness.

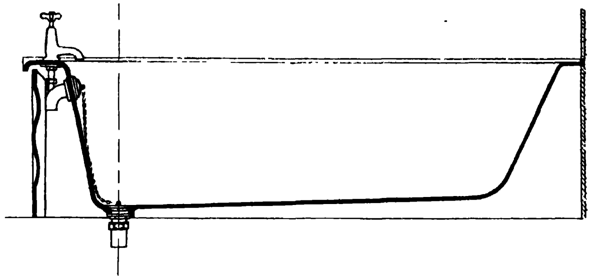
Baths

Materials. Fitments are made of marble, fire-clay, cast-iron, sheet copper, sheet and plate zinc, and sheet steel. Fire-clay and cast-iron baths should be porcelain-enamelled inside and either porcelain- or metallic-enamelled outside; copper tinned and planished; and steel tinned or galvanized. A common and unsatisfactory finish for metal baths is japanning, i.e. a coating of metallic enamel or hard varnish stoved on.

The use of marble is exceptional owing to cost. Porcelain-enamelled fire-clay baths are excellent but are heavy and absorb much heat; consequently their selection is largely restricted to public baths, institutions, and premises provided with plenty of hot water. For movable baths where lightness is essential, copper, zinc, and steel are handy, but the inapplicability of a porcelain-enamel finish renders them inferior to cast-iron. Porcelain-enamelled cast-iron baths hold the premier position in respect of general usefulness.

Types

Bath fitments are designed for specified purposes as indicated by their description, viz., plunge (or slipper), shower, spray, douche, hip, foot, &c.



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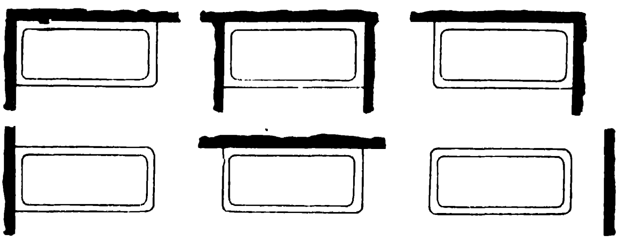

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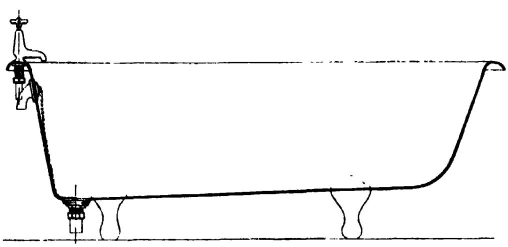

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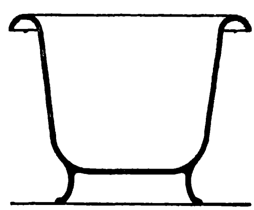

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FIG. 209. Doulton's 'Delphian' porcelain-enamelled cast-iron bath with panels. FIG. 210. Positions for baths. FIG. 211. Doulton's independent bath with roll edge. FIG. 212. Section of bath with base cast in one piece.

Plunge-baths are of two distinct types—enclosed and unenclosed. Old-fashioned enclosed baths were provided with either a flat edge or rim and wooden top and casing, the enclosure thus formed being difficult of access for

cleansing and all too often used as a store for unwanted articles and rubbish—hence their disrepute. Modern enclosed fitments have no such character, for they are made in one piece of fire-clay or cast iron, or with enamelled-iron, tile, or marble panels so as to fit close to wall and floor and

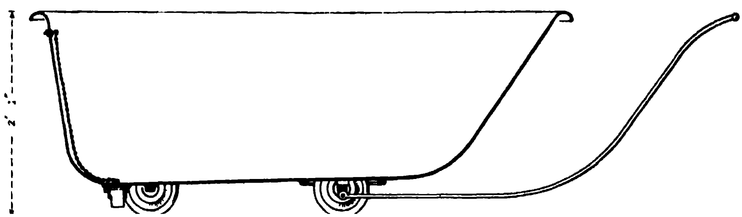


FIG. 213. Macfarlane's cast-iron hospital bath with rubber-tyred wheels and front wheels on movable axle.

exclude dust, with waste-fittings either exposed or discharging through an access partition wall. Fig. 209 illustrates a cast-iron bath of this type fitted with removable panels for access to valves, and Fig. 210 the varied positions for which it is designed.

Unenclosed independent baths fitted (in the case of iron fitments) with base or feet and (in the case of fire-clay baths) with foot-rests, are most commonly used. Figs. 211 and 212 illustrate the type. 'Roll' edges are needed, and a base is better than feet as it avoids any chance of dirt collecting under the bath. Such fitments should be fixed at a sufficient distance from the wall or walls to allow of proper access. For institutional use they are best fixed end-on to a wall with sufficient space at each side for access and facilitating attendance by nurses on the patients. The edges of the fitment should be rounded, and enclosed supply and waste valves are essential, the valves, to prevent misuse, being operated by a loose key.

Folding or tip-up baths are useful for positions where room-space is restricted. Such fitments should be of galvanized sheet steel or other light metal with the outlet arranged for discharging into a shallow sink or curb-surrounded waste outlet at the floor-level. A bath utiliz-

able where space is limited may be had fitted with rollers and a swivel outlet, permitting storage under a bench, table, &c.

Portable hospital or ward baths are best made of cast-iron with porcelain-enamel finish. These fitments should have

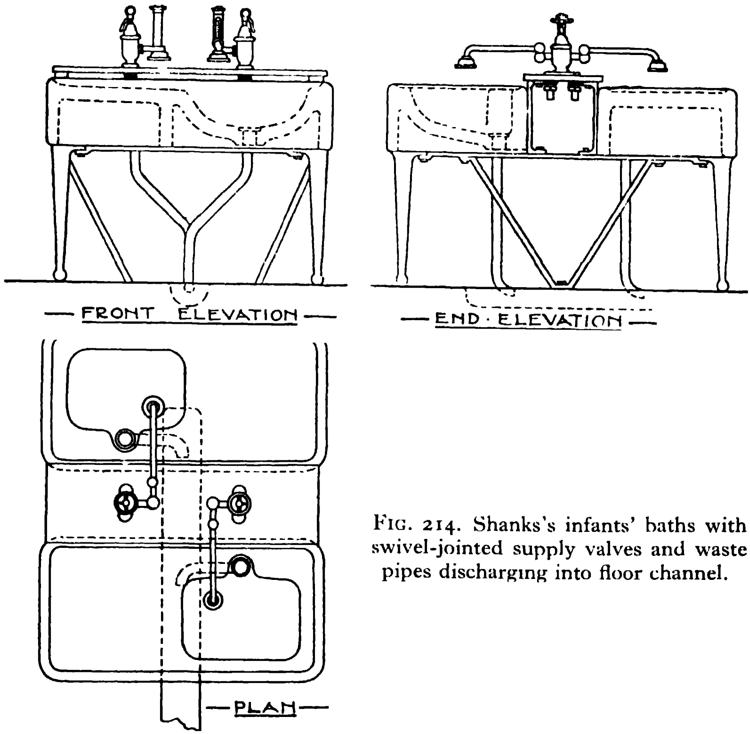
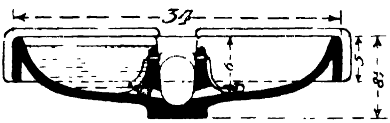


FIG. 214. Shanks's infants' baths with swivel-jointed supply valves and waste pipes discharging into floor channel.

a roll edge, swivel carriage, rubber-tired wheels, and a plug or valve outlet for discharging over a floor sink, or trapped waste pipe or drain at floor-level (Fig. 213).

Children's baths.—Nursery and institutional baths may be small replicas of the usual type, or on legs or pedestal. The usual measurements approximate to 2 ft. 6 in. × 1 ft. 8 in. × 10 in. In schools, square foot-baths about 3 ft. × 3 ft. × 10 in. fixed at the floor-level are usable for body bathing. For hospital maternity wards and infants' welfare centres porcelain-finished baths as illustrated in

Fig. 214 have been designed for fitting up in ranges, with swivel-jointed supply-valves and wastes discharging into a centre channel. As seen, the baths present the appearance of lavatory basins with enlarged slab top, supported on iron frames and legs, with a bracket support for shelf. Another design is shown in Fig. 215.



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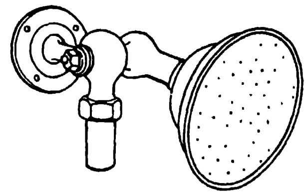

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FIG. 215. 'King's College' infants' baths (Leeds Fireclay Co., Ltd.).
FIG. 216. Shanks's swivel rose spray.

Shower-baths are a great asset in an ordinary residence and of very definite utility in schools and other places where a number of persons need bathing in a short space of time.

For private use a shower arrangement can be fitted to a plunge-bath. Given an impervious floor sloping to a waste outlet, or the provision of a fire-clay or enamelled cast-iron receiver with a waste outlet, a wall fitment of the kind shown in Fig. 218 can be fixed in a cubicle or used in conjunction with a waterproof curtain for securing privacy and preventing splashing. In schools they are often used without such surrounds.

Sprays can be attached to all kinds of shower-bath enclosures in the form of a series of perforated pipes, or in the form of a separate fitment as a 'needle' bath consisting of spray tubes alone or conjoined with wave, douche, and shower attachments, splashing being prevented by a metal or reinforced glass enclosure, or a waterproof curtain. Unless the floor is impervious and drained a sole plate or receiver with waste outlet should be provided.

For schools and other similar premises a rose spray is the most efficient form fixed independent of or within a cubicle. Swivel fittings of the kind shown in Fig. 216, if

fixed in pairs at suitable angles, are satisfactory and serve the double purpose of shower and spray. This form can often serve as a substitute for a plunge-bath and, compared with the latter, economizes time, water, and floor-space.

Sitz baths are fitted with a hip or back spray or wave and an ascending jet. If provided—as is usual—with a standing waste they can be utilized as foot-baths. The ascending jet serves the purpose specifically provided for in a bidet.

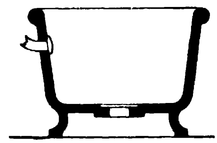


FIG. 217. Porcelain-enamelled fire-clay foot-bath with waste outlet and combined inlet for hot and cold water.

Foot-baths have a marked usefulness in all schools, institutions, and sports' pavilions and are often installed as an accessory to a swimming-bath. The fitments may be designed for solo use, as in Figs. 217 and 218, or in ranges, the water-supply being controlled by an ordinary valve, a valve with a loose key, or in the case of a range by a single valve.

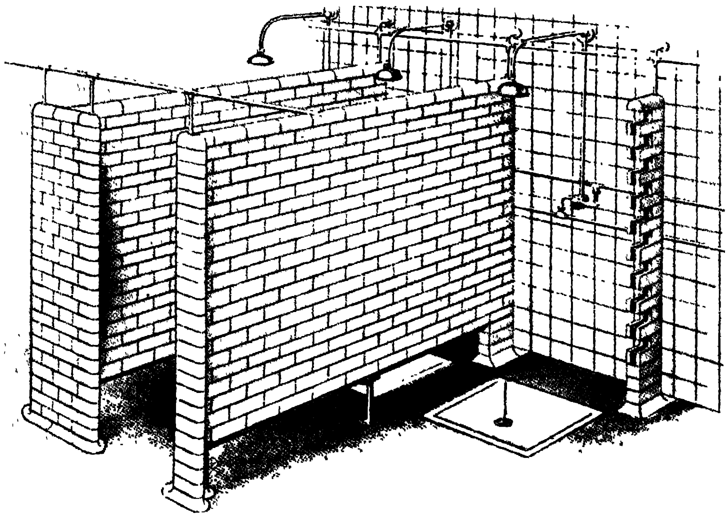
Factory baths.—In factories and workshops where lead, arsenic, or any other poisonous substance is used suitable washing conveniences must be provided (see Chapter IX, p. 158). Fig. 218 illustrates cubicles fitted with shower- and foot-baths, and Fig. 219 an excellent yet simple installation designed for a well-known chemical works and meeting with the approval of the supervising authority. For hanging and drying clothes the arrangement illustrated by Fig. 220 is satisfactory.

Colliery or miners' baths.—The arrangement for hanging and drying clothes and the construction of cubicles, as given, respectively, in Figs. 220 and 218, comply with the regulations,[1] the shower fitting being controlled by separate screw-down valves or by a safety or non-scalding valve as in the illustration, and the waste water drained into a continuous channel.

Swimming-baths.—Recent years have disclosed a growing tendency towards the installation of swimming-baths

[1] See Chapter IX, p. 159.

or ponds in schools, institutes, and club premises. The materials used and the methods of construction vary, but in all instances it is essential that attention should be



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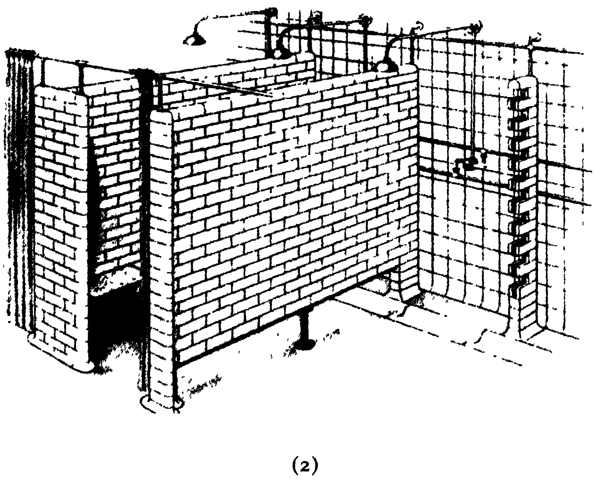
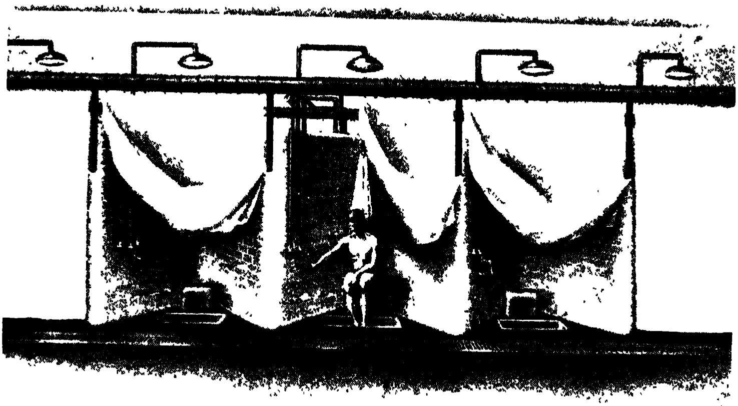


(2)

FIG. 218. (1) Cubicle with shower, foot-bath, and non-scalding valve (Leeds Fireclay Co., Ltd.).

(2) Cubicles fitted with shower fitments and seats to comply with the Coal Mines Act, 1911 (Leeds Fireclay Co., Ltd.).

given to the details of floor drainage, lining of floor and sides with a material which discloses dirt and can be easily cleaned, and the provision of a scum channel and a



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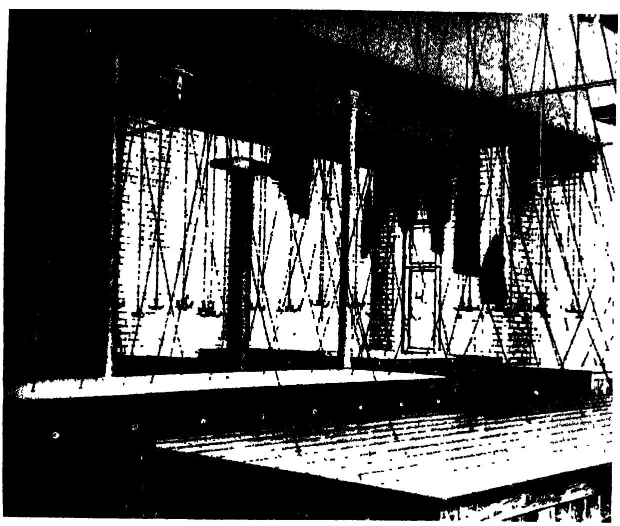

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FIG. 219. Shower and foot-bath installation with non-scalding supply valves and waterproof screening curtains (Leeds Fireclay Co., Ltd.).

FIG. 220. Clothes drying and storing room to meet regulations made under the Coal Mines Acts (Leeds Fireclay Co., Ltd.).

sufficient number of spittoons. Fig. 221 illustrates details of a bath lined with patent glazed bricks and fitted with scum channel, &c.

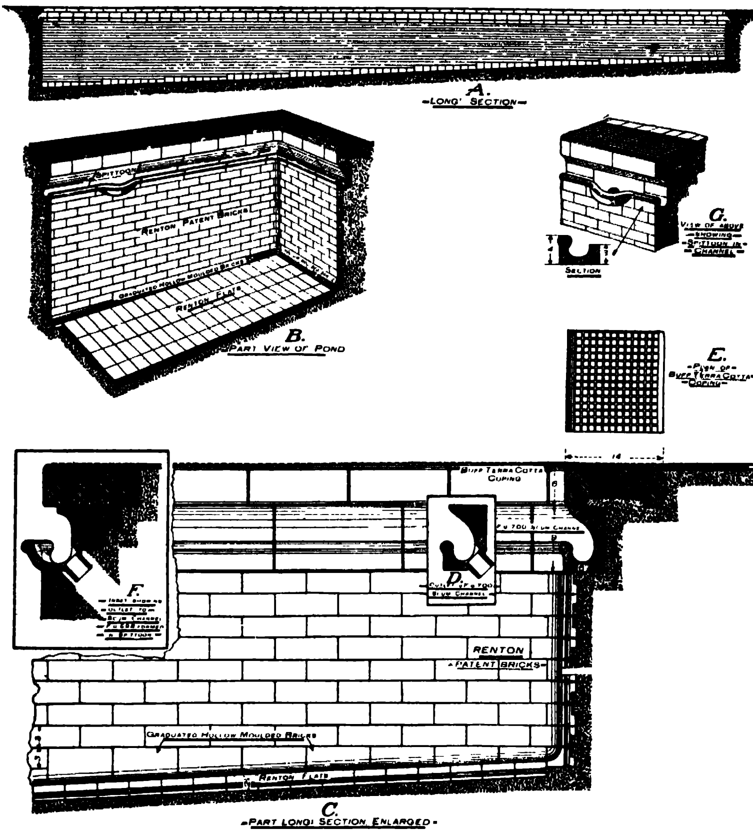


FIG. 221. Swimming-bath. Details showing glazed brick lining, scum channel, and spittoons (Leeds Fireclay Co., Ltd.).

Attention is sometimes drawn to the unsatisfactory condition of the water in such baths. The water is likely to be seriously polluted by the persons of the bathers, dried secretions and dead epithelium from the skin together with accumulated dirt being the most obvious source of pollution. Spitting and micturating in the water also cause serious pollution and may conceivably be the means of

distributing infective germs. Certain infections of the ear and naso-pharynx have been attributed to this source. Such risks of pollution point to the advisability of providing ablutionary facilities in the form of shower- and foot-baths for personal cleansing prior to the use of the swimming-

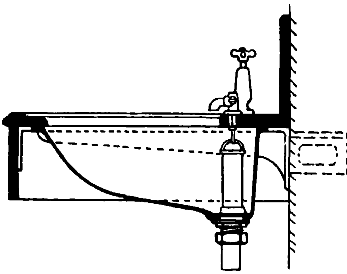


FIG. 222. Doulton's 'Savoy' lavatory with Queensware basin, marble top and skirting.

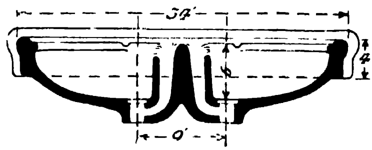


FIG. 223. Back-to-back lavatory basins in one piece of ware (Leeds Fireclay Co., Ltd.).

bath, spittoons alongside the bath, and adequate urinal and water-closet accommodation in a position readily accessible from the bath enclosure, coupled with sufficient supervision to prevent misuse of the bath water.

A common practice is to supply daily a quantity of clean water sufficient to make good the water splashed over and discharged via the scum channel. This, however, is not sufficient effectually to change the contents of the bath and maintain an adequate standard of water cleanliness, and the bath therefore should be emptied and refilled with clean water, the frequency of such change depending upon the number and class of bathers using the pond.

Frequent change of the bath water is often expensive when derived from a public water company. Where this is so it is a sound financial proposition to install a system of filtration so as to re-use the water. The usual methods of water purification aim at oxydizing the polluting matters by intensive aeration.

Lavatory Basins

Of the materials employed, iron if uncoated is dirty, if metallic-enamelled is non-lasting, and if porcelain-

enamelled is easily damaged. Salt-glazed ware is strong but the finished surface is somewhat rough and retentive of dirt. Porcelain-enamelled fire-clay, and porcelain, pottery, or china are satisfactory, an excellent example of the latter

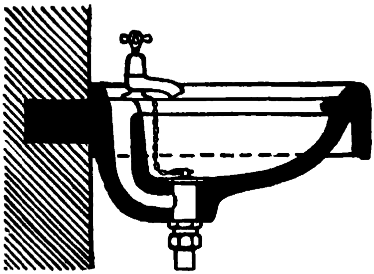


FIG. 224. One-piece earthenware lavatory basin with plug waste outlet and lugs for building into wall (Leeds Fireclay Co., Ltd.).

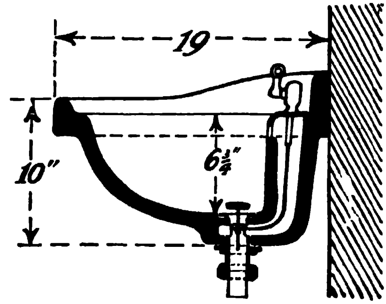


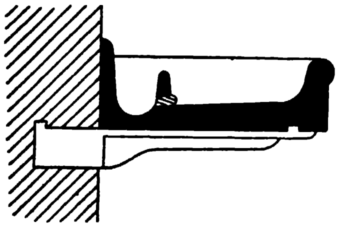
FIG. 225. One-piece earthenware lavatory basin with 'pop-up' waste (Leeds Fireclay Co., Ltd.).

being vitreous china, which is of one texture throughout and therefore not subject to surface crazing nor chipping.

Fitments may be classified as 'made-up'—with the basin made of one of the materials referred to above and a top slab, &c., of marble, slate, glass, or glazed ware (Fig. 222); and 'one-piece'—consisting of basin and top of a single piece of ware. All 'made-up' fitments have the disadvantage of dirt-accumulating internal angles and joints. 'One-piece' fitments of good materials, finish, and well-designed shape are sanitarily the best, for they afford the least opportunity for the retention of dirt and soapy debris—a qualification of the highest importance in every situation.

The selection of a pattern depends upon cost, position, and intended use. Fitments of special design are obtainable for bedrooms, bathrooms, public conveniences, hairdressers' and manicurists' establishments, schools, factories, hospitals, and for surgeons' and dentists' use. Whatever the type or pattern, every part should be accessible for cleansing, and therefore an open overflow of the weir type or a combined removable standing waste and overflow may be regarded as indispensable.

'Island' fitments should be fixed on plain enamelled or galvanized-iron frames and legs, or, in the case of a single fitment, on a pedestal. The basins in ranges of fitments may be isolated, or adjoin with butt or overlapped joints.



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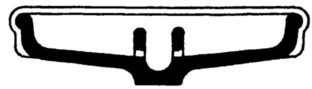

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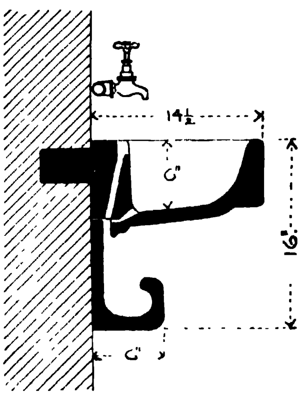

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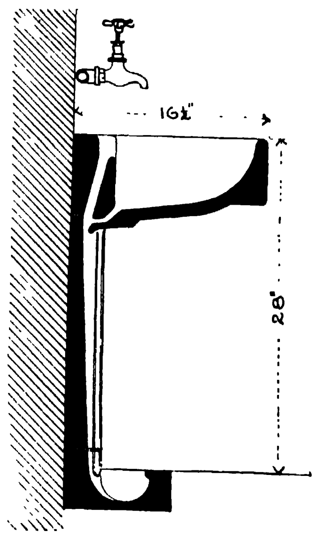

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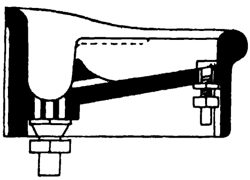
FIG. 226. Section of lavatory basin range with open channel waste (Leeds Fireclay Co., Ltd.). FIG. 227. Island lavatory with back-to-back basins in one piece and open channel waste (Leeds Fireclay Co., Ltd.). FIG. 228. Lavatory basin with continuous open channel waste (Leeds Fireclay Co., Ltd.). FIG. 229. Lavatory basin with open 'chute' waste (Leeds Fireclay Co., Ltd.).

For adult use from 20 to 24 in. should be allowed from centre to centre; for children's use, 15 to 18 in. (Fig. 223).

Figs. 224 and 225 are earthenware basins suitable for use in residences, hotels, and premises generally; the former fixed by lugs built into the wall, and the latter on brackets, with or without a towel rail.

Basins with 'open-channel' wastes.—A somewhat exceptional arrangement of an open waste-channel for ranges of two or three basins made in one piece of ware is illustrated in Figs. 226 and 227. This channel has the advantage of accessibility and a reduction in the number of traps and



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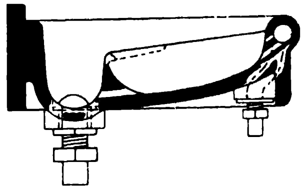


231

FIG. 230. Shanks's school lavatory basin with 'spreader' supply.
FIG. 231. Shanks's school lavatory basin with 'rim' supply.

length of waste pipe where separate trapping of the basins is otherwise favoured.

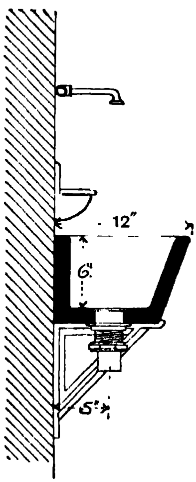
Accessibility and the avoidance of waste pipes are also the paramount features of the channel and chute wastes respectively given in Figs. 228 and 229, which are applicable to ranges of any length. The use of such channels and chutes may be commended for hospital and other installations where accessibility for the maintenance of meticulous cleanliness is the chief desideratum. For schools, in place of water-retaining basins, 'drain-away' basins with a continuous flow of water are sometimes advocated as a preventative against the spread of infection through the use of the same ablutionary water by more than one child. Figs. 230 and 231 illustrate patterns where the supply is through a 'spreader' or flushing rim, and discharges in a continuous stream over a weir into an open waste-channel.

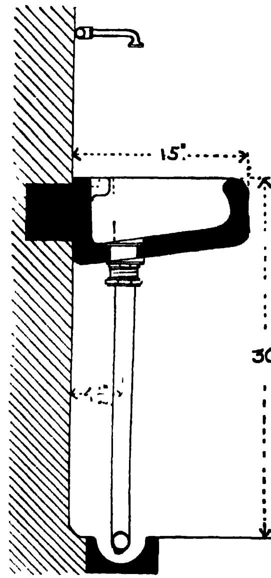
Fitments designed with the same object are the 'drain-away' troughs fitted with spray nozzles as illustrated by Figs. 232 and 233. Double troughs of this kind for island positions are obtainable. The type is also much favoured in factories as it permits of 'quick' ablutions.

The water-supply to weir basins is usually controlled by a single valve with loose key. Trough fitments

in schools should be controlled likewise, but with the provision of one direct-action spray for individual use. In factories the supply may take the form of sprays with taps under the control of the users of the several basins.

In hospitals it is both necessary and customary to pro-



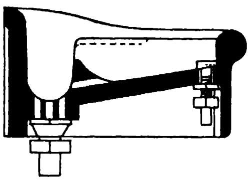


232 233

FIG. 232. 'Drain-away' lavatory trough with 'spray' supply (Leeds Fireclay Co., Ltd.).
FIG. 233. 'Drain-away' lavatory trough with 'spray' supply (Leeds Fireclay Co., Ltd.).

vide basins with supply and waste valves operated by elbow, knee, or foot action so as to avoid fouling of the fittings—of which many patterns are available. Fig. 234 illustrates a wall basin for an operating or post-mortem room with knee-action standing waste and overflow and treadle-action supply valves; and Fig. 235 a basin fixed clear of the wall with a mixing valve supply and standing waste and overflow. All valves, exposed waste-pipes, and brackets for hospital fitments should be porcelain-enamelled.

Basins with 'open-channel' wastes.—A somewhat exceptional arrangement of an open waste-channel for ranges of two or three basins made in one piece of ware is illustrated in Figs. 226 and 227. This channel has the advantage of accessibility and a reduction in the number of traps and



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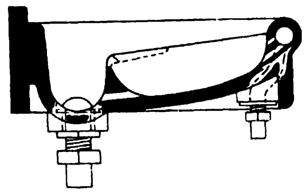


231

FIG. 230. Shanks's school lavatory basin with 'spreader' supply.
FIG. 231. Shanks's school lavatory basin with 'rim' supply.

length of waste pipe where separate trapping of the basins is otherwise favoured.

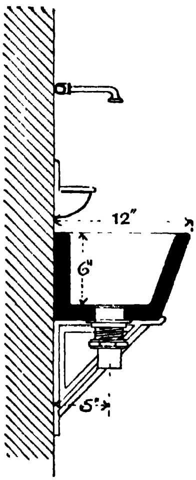
Accessibility and the avoidance of waste pipes are also the paramount features of the channel and chute wastes respectively given in Figs. 228 and 229, which are applicable to ranges of any length. The use of such channels and chutes may be commended for hospital and other installations where accessibility for the maintenance of meticulous cleanliness is the chief desideratum. For schools, in place of water-retaining basins, 'drain-away' basins with a continuous flow of water are sometimes advocated as a preventative against the spread of infection through the use of the same ablutionary water by more than one child. Figs. 230 and 231 illustrate patterns where the supply is through a 'spreader' or flushing rim, and discharges in a continuous stream over a weir into an open waste-channel.

Fitments designed with the same object are the 'drain-away' troughs fitted with spray nozzles as illustrated by Figs. 232 and 233. Double troughs of this kind for island positions are obtainable. The type is also much favoured in factories as it permits of 'quick' ablutions.

The water-supply to weir basins is usually controlled by a single valve with loose key. Trough fitments

in schools should be controlled likewise, but with the provision of one direct-action spray for individual use. In factories the supply may take the form of sprays with taps under the control of the users of the several basins.

In hospitals it is both necessary and customary to pro-



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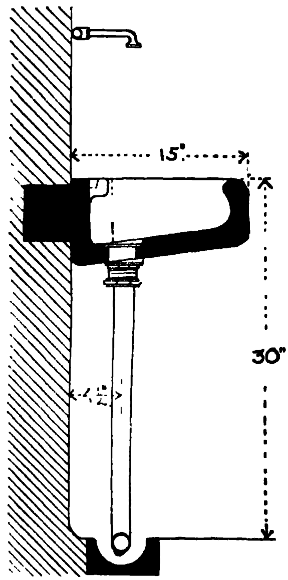

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FIG. 232. 'Drain-away' lavatory trough with 'spray' supply (Leeds Fireclay Co., Ltd.).

FIG. 233. 'Drain-away' lavatory trough with 'spray' supply (Leeds Fireclay Co., Ltd.).

vide basins with supply and waste valves operated by elbow, knee, or foot action so as to avoid fouling of the fittings—of which many patterns are available. Fig. 234 illustrates a wall basin for an operating or post-mortem room with knee-action standing waste and overflow and treadle-action supply valves; and Fig. 235, a basin fixed clear of the wall with a mixing valve supply and standing waste and overflow. All valves, exposed waste-pipes, and brackets for hospital fitments should be porcelain-enamelled.

Bidets

As an ancillary to the sanitary and ablutionary fitments in common use the bidet is now being installed in private dwellings and hotels to a much greater extent than formerly, the fitment being given the fuller recognition

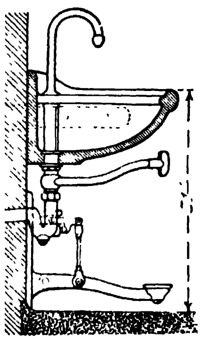

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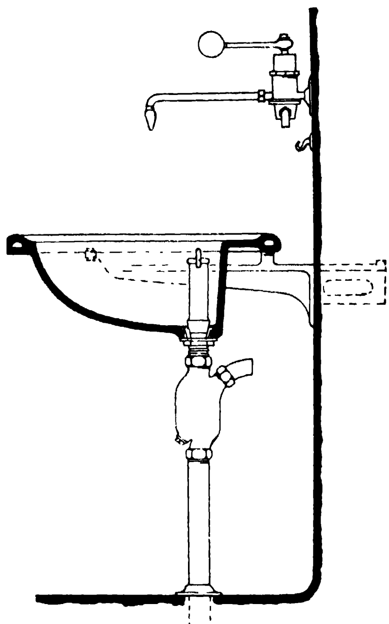
FIG. 234. Lavatory basins for operating or post-mortem room with knee-action waste outlet and treadle-action supply valves (Leeds Fireclay Co., Ltd.).

FIG. 235. Doulton's surgeon's lavatory basin with mixing-valve supply, standing waste, and overflow.



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which acquaintance with its merits and general usefulness as an aid to personal cleanliness deserves.

Modern fitments are made in white glazed earthenware as a pedestal basin with a perforated rim (called a flushing rim though not distinctively so), hot- and cold-water supply valves, and an upward discharging jet. In addition to supplying the jet, hot water is needed to warm the basin rim which forms the seat. Water is retainable in the basin by means of a chain plug or a combined standing waste and overflow. The latter should be of a pattern which can be lifted out for cleansing. Fig. 236

illustrates a fitment with plug and chain waste and open overflow.

Supply Valves

The fittings presenting the cleanest appearance and entailing the smallest amount of attention to keep clean are those with an exterior finish of porcelain enamel, either as a coating on the exposed metal parts or a casing of china. This finish is clean, labour-saving, and durable.

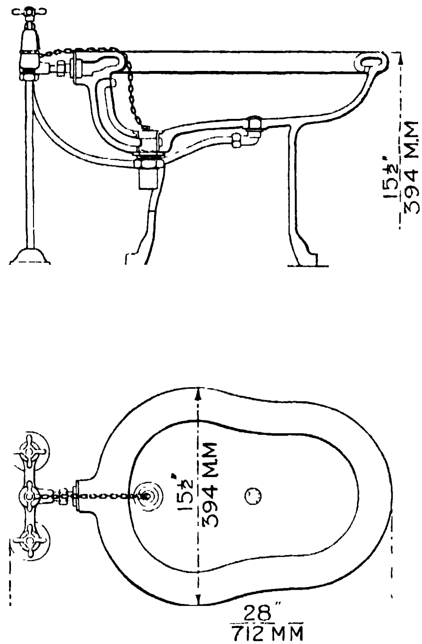


FIG. 236. Shanks's bidet with flushing rim, plug and chain waste outlet, and open overflow.

A satisfactory enamel coating is 'Cameo', which is applicable to metal valves, waste fittings, traps, supply- and waste-pipes, brackets, &c. As a casing for working valves vitreous china is non-porous and non-crazing and possesses great strength and resistance to heat. 'Smooth-body' pattern valves are less liable to accrete dirt and are easier to clean; therefore if plain metal valves are used they should follow this pattern. 'Mixing' or 'non-scalding' valves should be obligatory for all shower, spray, and shampoo fittings, and for plunge-baths in hospitals, institutions, and public baths (Fig. 237). A valve of this type should effectually mix the hot and cold water, giving first cold, then tepid or mixed, and finally hot water only. The valve may be fitted with a stop at 'mixed' so as to prevent scalding. For institutional and other similar use the valves

are best operated by a loose key, in public baths from outside the apartment. In fixing, the internal diameter of the service pipe should be the same size as the valve inlet, the pressures of the hot-and-cold supplies regulated so as to

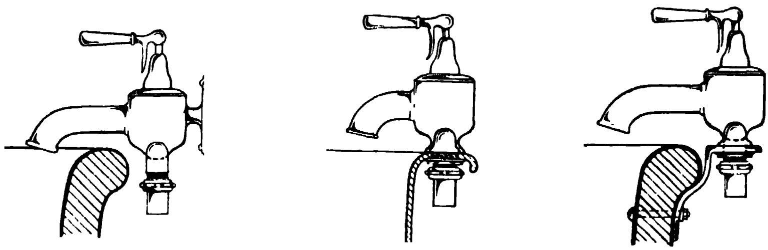
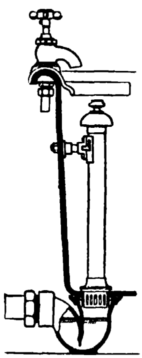


FIG. 237. Shanks's 'Duplex' mixing fitting for attachment to wall, roll of cast-iron bath, and fire-clay bath.



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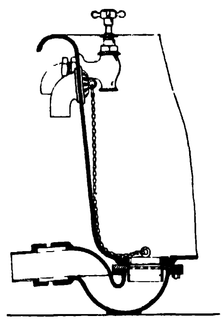

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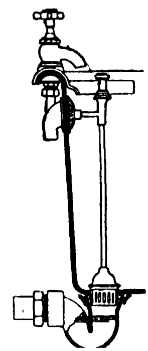


240

FIG. 238. Combined standing waste and overflow.
FIG. 239. Plug waste outlet with separate overflow.
FIG. 240. Rod waste outlet with separate overflow.

be approximately equal, and the relative supplies so regulated as to provide an ultimate water temperature of 100° F. For high-pressure mains a reducing valve, such as Shank's 'Sensitive', can be fitted.

The Model by-laws[1] provide as follows:

'Every water inlet to a fixed bath or fixed lavatory basin shall be distinct from, and unconnected with, the outlet thereof, and

[1] *Model By-laws for preventing the waste, &c., of water*, Series XXI, 1926. Ministry of Health.

any outlet for emptying a fixed bath or fixed lavatory basin shall be provided with a visible and well-fitting water-tight plug or other easily accessible and equally suitable outlet.

'If the cold water to a fixed bath or fixed lavatory basin be supplied otherwise than through a cistern, the level of the nose or outlet of the cold-water inlet shall be above the level of the overflow pipe or, if there be no overflow pipe, of the rim of the bath or basin.'

Waste Outlets

The waste outlet fittings of baths and lavatory basins should be of the open or unenclosed pattern with every part readily accessible for cleaning. Figs. 238 to 240 give examples (Messrs. Walter Macfarlane & Co.).

Overflows

The most sanitary arrangement for a bath is an exposed combined standing waste and overflow, removable for cleaning. For basins, the same type or an open overflow as in Fig. 224. Baths and lavatory basins other than those with a combined standing waste and overflow, or with an overflow made as a part of the fitment and discharging into the waste outlet, require a specially fitted pipe. If the waste discharges into a channel the overflow can be similarly arranged. Where this is not possible the pipe can either be carried to the outer air as a warning pipe or connected to the trap of waste-pipe above the water-level. The Model by-laws[1] state:

'Every overflow pipe provided in connexion with a bath, lavatory basin, or sink shall be so fixed that its outlet, or the outlet of any waste-pipe with which it communicates, shall, where practicable, be in an exposed and conspicuous position where the discharge of the water may be readily seen.'

[1] See footnote 1, p. 354.

XX

SINKS AND SPECIAL FITMENTS

SINKS for the reception of waste water are required in all residential buildings and also in many premises reserved for commercial purposes, as drain-away fitments for clean waste water from draw-off taps, or water fouled by domestic use, or for containing water for washing up dirty utensils, cleaning vegetables, pots and pans, or for special use in chemical works and laboratories; in every case coupled with arrangements for removing the waste water or liquids.

Materials

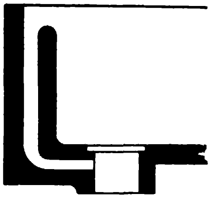
For ordinary use enamelled fire-clay is to be preferred; for scouring pots and pans liable to damage an enamelled surface—galvanized iron or steel. For washing up glass and china teak fitments cause less breakages, but the material is unsuited for the cleansing of greasy articles. If metal linings are employed all internal angles of the wood casings should be rounded so as to prevent dirt accumulation, and the mode of fixing the lining should allow for expansion of the metal. The choice for chemical works and laboratories is practically confined to salt-glazed stoneware, fire-clay coated with a special non-solvent enamel, and lead-lined sinks.

'Shallow' and 'Deep' Sinks

The former usually range from 5 to 8 in. deep overall, and the latter from 7 to 12 in., and are frequently described respectively as 'London' and 'Belfast' patterns. The 'deep' pattern is commonly provided with an overflow and a waste outlet fitted with a plug and chain or a combined standing waste and overflow, enabling the sink to be filled with water for washing-up purposes, and for domestic use is largely supplanting the 'shallow' pattern owing to its utility. The 'deep' sinks have the further advantage of

being usable as wash-tubs. Fig. 241 shows a section of a deep sink with accessible weir overflow.

Double sinks as given in Fig. 242 provide for the washing of greasy articles in one half and rinsing in the other,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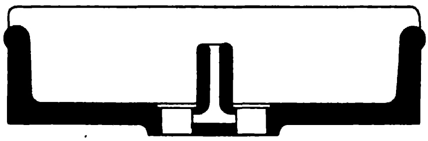
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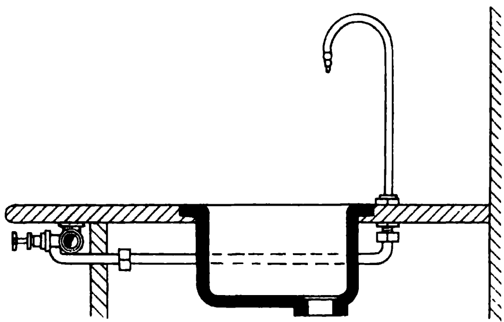
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FIG. 241. Part section of deep sink with accessible weir overflow.

FIG. 242. Double sink with accessible weir overflow.

FIG. 243. Laboratory sink fitted in bench top with swan-neck supply and control valve.

or for steeping and rinsing clothes, teakwood drainers being fitted suitable for either half. For such sinks a swivel nozzle supply valve is useful.

Drainers should be of teak or other hard wood, or enamelled fire-clay.

Hospital Sinks

For use in hospitals any good type of fitment finished white porcelain enamel both inside and outside may be regarded as suitable if fixed on enamelled iron or ware brackets sufficiently clear of the wall to allow of access for cleaning, and fitted, as required, with knee- or elbow-

action waste outlet and arm- or elbow-action supply valves or similarly operated waste and valves. The combination of a draw-off sink with a scalding-, or bed-pan-, or slop-sink is often favoured.

Drip Sinks

A sink large enough to hold an ordinary pail and furnished with a waste pipe should always be provided for receiving drippings from draw-off taps, preferably of enamelled earthenware.

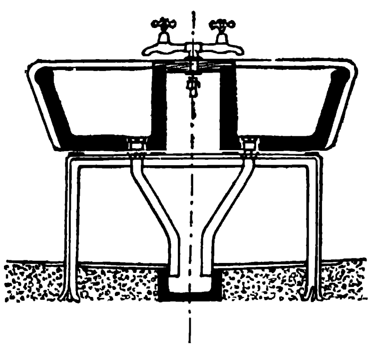


FIG. 244. Wash-tubs for island position with waste pipes discharging into floor channel.

Sinks for Chemical Laboratories, &c.

These are finished with a plain or roll edge for independent positions, or a square, flat edge to fit the underside of benching, or a projecting rim to fit in rebate of bench; in each pattern with or without an anti-splash flange. The enamel should be acid-resisting. Fig. 243 illustrates a sink fitted in rebated opening in bench top with water-supply arrangement as usually provided.

Wash-tubs

In wash-houses, whether public or attached to blocks of tenements or institutions, wash-tubs are requisite: they are also useful fitments in ordinary dwelling-houses. In some districts it is customary to fix such a fitment in cottages and other dwellings as a corollary to the scullery sink. In addition to clothes' washing the fitment is usable, where other facilities are lacking, as a child's bath.

The tubs can be fixed singly or in ranges, against a wall on cantilevers, or in island positions (Fig. 244). The materials used are glazed stoneware and porcelain-enamelled iron and fire-clay.

For institutions, steeping tubs (generally made of galvanized steel or enamelled cast-iron) are useful adjuncts to a series of wash-tubs.

Waste Outlets and Fittings

Shallow sinks are mostly fitted with plain grated outlets, which should be in the form of cobweb gratings fitting an

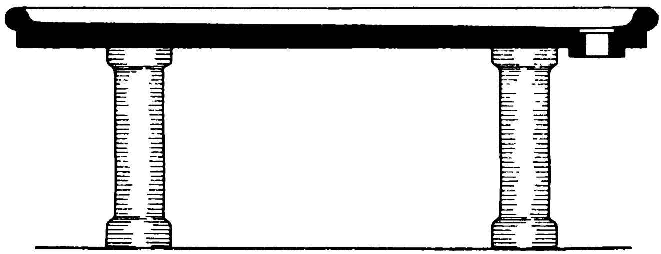


FIG. 245. Enamelled fire-clay mortuary reception slab on pedestals.

orifice of larger diameter than the waste pipe so as to facilitate a free outflow.

Deep sinks should have a plug and chain, or a combined standing waste and overflow of vulcanite or other material which will not damage the enamelled surface of the sink. The outlets of sinks used for cleaning pots and pans or washing vegetables require strainers to keep sand, &c., out of the trap.

The waste outlets and pipes of sinks receiving chemicals need special selection. Brass and gun-metal are unsuitable owing to the ease with which the metals are corroded. Plugs and standing wastes and overflows can be of lignum vitae, india-rubber, or vulcanite, fitting into vulcanite washers or lead liners; or of glazed ware ground into pottery nozzles.

For wash-tubs a plug and chain is the best stopper. Single fitments can be trapped immediately under the fitment, but this is not essential if the waste pipe is short and discharges into a channel leading to a drain inlet. Ranges should have short down-pipes discharging into a floor channel, as in Fig. 244.

Valves and Overflows

See Chapter XIX, pp. 353 and 355.

Supports for Sinks, &c.

For wall fitments cantilever brackets of galvanized or porcelain-enamelled iron or enamelled ware cannot be im-

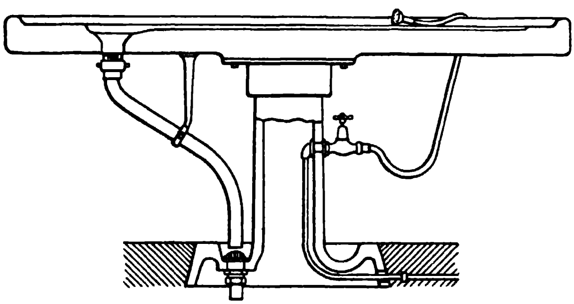


FIG. 246. Shanks's revolving post-mortem table and pedestal fitted with water-supply and waste pipe.

proved upon. For island fitments iron standards of the plainest design are better than pedestal supports, which form dirt-accumulating enclosures.

Mortuary Fitments

Lavatory basins and sinks of the operating theatre type (see Chapter XIX, p. 351) are necessary in mortuaries, together with reception slabs and a post-mortem table. The slabs may be of marble or enamelled fire-clay, with a slightly raised edge and drainage to a waste outlet having a short waste pipe or chute discharging to a floor channel leading to a drain inlet. Slate is used for slabs, but is not sufficiently non-porous.

Fig. 245 indicates a glazed fire-clay slab on pedestals, and Fig. 246 a section of a revolving post-mortem table and pedestal in white glazed Victorian fire-clay complete with waste pipe, channel, and outlet. In place of the waste outlet shown the down-pipe can be discharged into an ordinary floor channel.

Operating Theatre Tables

Fitments for such use are now most often made of white porcelain-enamelled cast-iron, with mechanism permitting several adjustments.

Drinking-water Fountains

Wall and other fountains necessitating the use of drinking cups, and bubbling fountains with a nozzle accessible to the drinker's mouth, may convey infection from one person to another. Bubbling fountains are a great improvement on the old type provided the jet orifice or nozzle is so placed as to make it impossible of access to the lips. Infant children, however, find it somewhat difficult to manipulate the press-down valve and at the same time drink from the jet. To meet such cases a constant-stream supply would appear to be the best arrangement.

XXI

DRAINAGE

IN London a sanitary authority is entitled to examine any drain, water-closet, earth-closet, privy, ash-pit, or cesspool, and any connected fitment or apparatus, and for this purpose, or to trace the course of a drain, may enter and open the ground after notice (or in urgent cases without notice) to the occupier, or, if the premises are unoccupied, to the owner;[1] a power limited in districts governed by the Public Health Act, 1875, to cases where an allegation is made that a drain, &c., is a nuisance or injurious to health, or where a written report is made by the surveyor or inspector that a drain is suspected of being dangerous or injurious to health.[2] The examination indicated may entail the application of a test to the drainage system.

Testing Old Drainage Work

So far as London is concerned the method of testing is unfettered and at the discretion of the sanitary authority, and chemical, smoke, air-pressure, and water-pressure tests are variously employed. No such freedom of action obtains in urban and rural districts, the test being restricted to smoke, coloured water, or other similar test, and then only with the consent of owner or occupier or on a court order. A water-pressure or hydraulic test is not employable.[3]

Testing New Drainage Work

The hands of the sanitary authority are not legislatively tied in regard to the form of test which may be applied, and although the by-laws in force in many districts limit

[1] The Metropolis Management Act, 1855, and Public Health (London) Act, 1891.

[2] Public Health Acts, 1875 and 1907.

[3] Public Health Act, 1907.

the specified requirements relating to the water-tightness of drains to the use of 'good sound pipes of glazed stoneware, heavy cast iron, or other equally suitable material' with 'suitable water-tight joints',[1] a water-pressure test is often applied. In London a definite minimum standard test is specified for drains, which must be capable of resisting a pressure of at least 2 ft. head of water; while soil, soil-ventilating, and waste and waste-ventilating pipes from urinals and slop-sinks must be gas-tight.[2]

The Standard Test

The hygienic axiom is that all pipes conveying foul waste matters should be both gas- and water-tight, and therefore it would appear to be superfluous to attempt any differentiation between old and new work, for obviously if a sound condition is essential for work newly constructed, it is equally essential that existing pipes provided for exactly similar uses should likewise be in a sound state, and this without regard to the date of construction. Consequently the test applied should be of a character definitely determining the state of the system to withstand a test which may at any moment be applied under working conditions, and in conducting a test attention should be focused on this aspect.

Applicable tests may be placed in order of reliability as follows: (1) water-pressure, (2) air-pressure, (3) smoke, and (4) chemical.

Provision of Drainage

The Public Health Acts[3] confer a power upon sanitary authorities to require the drainage of existing houses and buildings, and make it an offence to erect or re-erect, or to occupy buildings pulled down to the ground floor-level,

[1] Model By-laws, Urban, Series No. IV.

[2] Drainage By-laws made under the Metropolis Management Acts, 1855 and 1899. See footnote on p. 210.

[3] The Metropolis Management Act, 1855; the London County Council (General Powers) Act, 1920; and the Public Health Act, 1875.

without the provision of sufficient or effectual drains. Such requirement can include the provision and upkeep in good condition of a shoot, trough, gutter, or channel with a down-pipe or trunk for conveying rain-water from a roof so that such water does not fall upon persons using a street or flow over a footpath.[1]

If a sewer is within 100 ft.[2] of the building to be drained, communication with a sewer can be insisted upon; if a sewer is not within this distance, then the drains must discharge to a cesspool.

A separate drain can be demanded for buildings in different curtilages or a combined drain allowed; and a stipulation made that the lowest story of a new or re-erected building shall be placed at a level permitting drainage by gravitation to a sewer.[3] In London, basements below the level of the available sewer may be approved subject to the installation of suitable lifting appliances or apparatus for discharging the sewage into the sewer.[4]

Drains must be 'sufficient', 'efficient', or 'effectual',[5] i.e. of materials, size, level, and fall for the proper drainage of the premises—as determined by the sanitary authority. (See Chapters VII, VIII, IX, and X.)

In London[6] an appeal can be made to the county council against an act or order of a borough council in relation to the level of any building, the construction, repair, alteration, stopping, or filling up of any drain, or the cleansing, covering, filling up, or drainage of any pond, pool, ditch, drain, or place containing or used for the collection of

[1] The Towns Improvement Clauses Act, 1847; the London Building Act, 1894; and the Public Health Act, 1925.

[2] Extended by the Metropolis Management Act, 1862, to 200 ft. in the case of undeveloped sites in London.

[3] London County Council (General Powers) Act, 1920; and Model by-laws, Urban, Series IV, 1925.

[4] London County Council (General Powers) Act, 1920.

[5] Metropolis Management Act, 1855; Public Health Act, 1875; and London County Council (General Powers) Act, 1920.

[6] The Metropolis Management Act, 1855, and the Public Health (London) Act, 1891.

any drainage, filth, water, matter, or thing of an offensive nature, provided that the appeal is lodged within seven days of the act or notice or order. In districts subject to the Public Health Act, 1875, the appeal from an order or requirement of a sanitary authority is to the Minister of Health in any case where the authority may, in default of the owner, do the necessary works and recover the expenses, and in other cases to a court of quarter sessions.[1]

By-laws Controlling Construction of Drains

Sanitary authorities are empowered[2] to make by-laws governing the drainage of premises within their districts. Such by-laws are commonly based on a model code issued by the Minister of Health, but nevertheless show many divergencies as between one district and another. In London (excluding the City) the by-laws are made by the central authority—the London County Council—and administered by the borough councils, a procedure securing uniformity of practice throughout the county.

All by-laws require the approval of the Minister of Health; the provisions relate only to drains provided for the drainage of buildings; and, so far as London is concerned, to drains communicating with sewers. The codes generally impose upon persons about to construct, reconstruct, or alter drains or the attached sanitary fitments a duty of giving notice of such works to, and to deposit plans and particulars of the proposed works with, the sanitary authority.

The notices, plans, and particulars required differ in the sanitary districts, but they should always comprise sufficient details to indicate whether the proposed works are in accordance with the statutory provisions and the operative by-laws. Plans and particulars should be in duplicate, with the former clearly and indelibly made on cloth or

[1] The Public Health Acts, 1875, 1890, and 1907.

[2] The Metropolis Management Act, 1855, and the Public Health Acts, 1875 and 1890.

linen so as to form a permanent record when filed. The following specification[1] is a complete one and includes provisions for:

(1) *Construction.*

(*a*) *Deposit of plans, notices, &c.*—Notices, plans, sections, particulars and detailed descriptions to be signed by the builder or his agent and deposited 15 days before commencing erection of building or works; with 24 hours' notice of the day and time at which the work will be commenced.

(*b*) *Plans, sections, and particulars.*—Plans drawn to a scale (except in the case of block plans) of not less than 1 in. to every 16 ft. showing position of every soil and waste-water fitment and trap connected therewith; fall of every drain; position and size of every drain, means of access, gully, soil pipe, waste pipe, ventilating pipe, and rain-water pipe; positions of all windows and other openings into the building; height and position of all chimneys belonging to the building and within 20 ft. of the open end of a soil- or ventilating-pipe; levels of the lowest floor of the building and the adjoining street; and the level of any yard, ground, or open space belonging to the premises.

(*c*) *Block plan.*—A plan drawn to a scale of not less than 1 in. to every 22 ft. showing:

(i) Premises upon which such work is to be carried out.

(ii) Position of the buildings on such premises, and so much of the properties adjoining thereto as may be affected by such work.

(iii) Names of the streets or thoroughfares immediately adjoining such premises, and the number or designation of such premises.

(iv) Lines, size, depth, and inclination of the proposed drains, and, so far as can be ascertained without opening the ground, the lines, size, depth, and inclination of the existing drains, and the arrangements for the ventilation of the drains—the existing drains and the proposed drains to be distinctively indicated by different colours.

(v) Points of the compass.

Such block plan need not, however, be submitted if the particulars (i) to (v) are shown on the plan first mentioned.

[1] See footnote on p. 210.

(*d*) *Detailed description.*—Sufficiently describing intended mode of construction of the fitments, &c., mentioned in (*b*).

(2) *Additions, partial reconstruction or alteration.*—Such plans, sections, and particulars as may be necessary to enable the authority to ascertain whether the proposed works are in accordance with the statutes and by-laws. If plans, &c., have previously been deposited, then the date of deposit is sufficient, with a plan showing the new work and only so much of the existing work as will enable the relative positions to be seen.

(3) *Repair or partial reconstruction in urgent cases.*—Immediate notice of works and the deposit of plans, &c., within fifteen days of commencement.

A plan or section is not required for repairs not involving the alteration or the entire reconstruction; but a notice and a sufficient description is obligatory in every instance.

Definition of a 'Drain'

The determination of what is a 'drain' sometimes involves much ambiguity in respect of existing drainage systems, and in many instances pipes palpably laid as drains have, in the absence of proof that they were approved and constructed as private drains, obtained the legal status of sewers, with the corollary of maintenance by the sanitary authority instead of by the owner or owners of the premises drained.

The obvious intention of the statutes is to place upon an owner the responsibility of constructing and maintaining, as a drain, a pipe system provided on and for the drainage of private property, to which system no other person has a right of connexion; as distinct from the provision and maintenance, as a sewer, of a system by the ratepayers at large, to which system any person would have the right to connect a private drain.

Difficulties created in respect of existing systems by the form of words used in statutorily defining a 'drain', or by

any default of the sanitary authority in regard to approval or disapproval or the keeping of proper records, or any act of a builder or property owner, have no bearing upon the legal determination of a drain about to be constructed, for this is, in the statutes applying to London, defined as 'a drain used for the drainage of one building only or premises within the same curtilage, or for the drainage of a group of houses by a combined operation under the order of a sanitary authority, and communicating with a cesspool or other like receptacle for drainage, or with a sewer receiving the drainage of two or more buildings in different occupation';[1] and, by the statutes applicable to extra-metropolitan areas, as 'a drain used for the drainage of one building only or premises within the same curtilage; or two or more houses in different ownerships';[2] the interpretation of the last mentioned apparently depending upon its construction as a private drain on private property, to which drain no other person would have the right of connexion.

A drain can be either above or below ground and used merely for conveying surface- or rain-water. From a legal aspect a pipe conducting rain-water from a roof is a drain.

'Combined' and 'Separate' Systems of Drainage

Waste matters to be removed from premises comprise faecal matter from soil fitments, water fouled by domestic use, and rain-water falling upon roofs and other surfaces, which may be conveyed from the premises by a single system of drainage, or by separate drains—one for sewage or foul matters and one for surface-water; the system adopted being signified by the expressions 'combined' and 'separate'.

In districts where the sanitary authority has provided or has the right to use a sewer limited to the conveyance of surface-water, separate drains for sewage and surface-

[1] The Metropolis Management Acts of 1855 and 1862.

[2] The Public Health Acts of 1875 and 1890.

water can be insisted upon; but where only one sewer is provided, and this for the conveyance of sewage, owners of premises can claim to discharge into such sewer both foul matters and surface-water.

Where sewage is discharged to a cesspool or to sewage disposal works on the premises or elsewhere, it is an advantage to reduce the volume of sewage to be disposed of or treated by excluding surface-water. On the other hand surface-water discharged into a sewage drain materially assists in keeping the interior in a clean condition.

The development of housing schemes has brought to the fore the considerable saving in cost effected by draining blocks or groups of buildings by a combined system. The relative position of the two systems is well expressed in a manual issued in 1919 by the Local Government Board in connexion with State-Aided Housing Schemes, and the views presented are worth reproducing:[1]

'Considerable economy could be effected, in connexion with the drainage of small dwellings, by the general adoption of the system of the common drain or sectional drainage. This consists of using a common drain to collect the drainage from a number of houses and to deliver at one point into the main sewer, instead of requiring each house to have its drainage system separately connected. The latter system involves separate disconnecting traps, manholes, and ventilating arrangements for each house, with a separate connexion cut across the road to the sewer. Where there is a duplicate system, two connexions, one to the sewer and the other to the rain-water drain, have to be provided for each house. The cost of these numerous connexions is increased where the roads are wide, or where the houses are set back from the road in a manner which for other reasons is most desirable. The saving in cost by the adoption of the common drain is substantial if only the works within the curtilage of the houses themselves are considered, but if the cost of cutting up the crust of the roadway after it is made, and of making good the damage resulting from settlement and reinstatement of such connexions is also taken into account, the economy which may be effected is very considerable. The adoption

[1] *Manual on the preparation of State-Aided Housing Schemes.*

of this system has undoubtedly been checked owing to the legal position, which is liable to throw on the local authority the responsibility of maintaining the common drain. This objection, however, largely disappears in the case of municipal housing schemes, in which case the local authority is at the same time the owner of the property.

'There can be no doubt that in certain cases, owing to the level of the land, for example, or to the short length of a road, the extension of a common drain slightly beyond the general limits that might be fixed would enable a sewer in a subsidiary road to be dispensed with altogether. It seems, therefore, undesirable to make too rigid rules as to the number of houses which may be drained into a common drain, but, as a general rule, the number should not exceed fourteen houses, exceptions being permitted only in cases where substantial convenience or economy would result.

'There must always be provided in the roadway a drain to carry off the surface-water. Where there is a combined system and the surface-water and sewage are both carried in the same pipe, the economy above suggested due to the extension of a common drain would not so frequently result, as the road drain would be required in any case for the surface-water. The question as to whether there should be a double or a single system frequently has to be determined on account of factors other than those of economy, but the expenses entailed in development are considerable, and should be taken into account in cases in which a double system is adopted to secure economy in sewage treatment. Where, however, the double system is adopted, the common rain-water drain is economical for the same reasons as the common soil drain.

'In addition to the economies which result from the combined drain, the actual drainage for each house may be considerably simplified. An excessive number of manholes is sometimes required in places where rodding eyes would answer all purposes; also the collection of the branches from bath and sink gullies into the branch from the soil drain will save length in branch drains and reduce the number of connexions with the common drains; moreover, a useful flush is provided for the soil drain by this means.

'The following requirements should be observed in connexion with the sectional system of drainage:

(i) One connexion to the sewer to serve a section generally not exceeding fourteen dwellings.

(ii) An intercepting trap and manhole to be placed on the common drain, within the section drained as near as convenient to the junction of the sewer.

(iii) The system to be ventilated in the following manner:

(*a*) A fresh-air inlet or vent-pipe to be placed at the manhole containing the intercepting trap.

(*b*) At the head of each common drain.

(*c*) Each separate block of dwellings to have a vent-pipe at or near the highest point of the common drain adjoining; the vent to be carried up clear of the eaves of the building.

Note.—Where blocks of dwellings have w.c.'s on the first floor connected to soil-pipes, the soil-pipes should be carried up as vent-pipes in the usual way; in that case the vent-pipes previously mentioned for each separate block should be omitted.

(iv) A manhole to be provided where two common drains form a junction.

(v) Inspection chambers or rodding eyes to be so placed that no length of drain exceeding 100 ft. in length is without means of clearing or examination. Rodding eyes to be provided also where a change in the direction of the drain, or a branch connexion, renders this desirable.

(vi) All pipe connexions to be by oblique bends and easy curves.

(vii) All connexions from the dwelling to be brought into the w.c. branch drain (as near the buildings as practicable) so that as few connexions as possible are required to the common drain.'

The provision of a combined drain for groups of houses erected by a private owner and intended for sale to different persons raises the possibility of future difficulties in regard to the maintenance of the drains by prospective purchasers, and the further possibility of the maintenance of the drains as 'sewers' being thrown upon the sanitary authority; but any differences between owners are capable of adjustment, and the possibility of an obligation being incurred by the sanitary authority can be avoided by the filing of a record showing approval of the system as a combined 'drain'.

Figs. 247 to 250 illustrate a group of houses drained on alternative systems:

(1) Each house drained separately into a sewer taking both sewage and surface-water.

(2) Each house drained separately: sewage and surface-water from rear of houses into sewage sewer, and surface-water from front of houses into surface-water drain or sewer.

(3) Combined drainage of group on lines of (1) and (2).

Connexion of Drains to Sewers

Any person has the right, on due notice and compliance with the prescribed regulations, to drain into a sewer within the district in which the premises are situate. In areas subject to the provisions of the Public Health Act, 1875, connexion is permissible to a sewer in an adjoining district by arrangement with the sanitary authority concerned, any difficulty as to terms being settled by arbitration or by appeal to a court of summary jurisdiction.

The construction of any part of a drain under a public thoroughfare and the connexion of a drain to a sewer are subject to compliance with the regulations of the sanitary authority. The authority is entitled[1] to make the connexion, and this procedure is the one mostly followed, payment of the estimated cost by the person responsible for the drainage work generally being required prior to the work being carried out.

A sanitary authority may, by agreement, construct drains on private property, but the practice is not largely followed except in relation to the alteration and reconstruction of combined drains in several ownerships.

Definitions of Drains for Specific Uses

A 'subsoil' drain may be defined as a drain used or constructed to be used solely for conveying to any sewer (either directly or through another drain) any water that

[1] Metropolis Management Act, 1855, and Public Health Act, 1925.

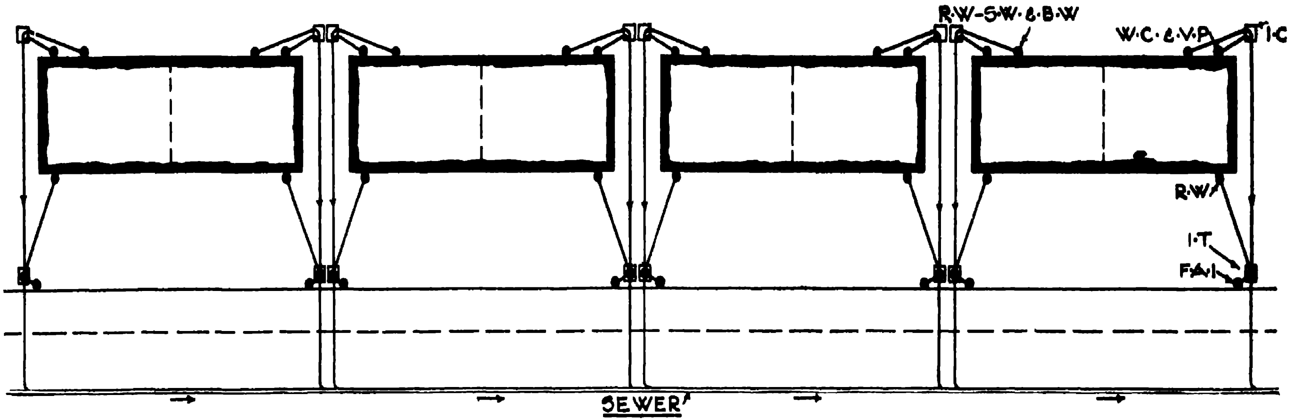


FIG. 247. Plan of drainage for eight houses with separate drain, conveying both sewage and surface water, for each house.

F.A.I.	Fresh-air inlet.	V.P.	Ventilating pipe.	S.W.	Sink waste gully trap.
I.T.	Intercepting trap.	W.C.	Water-closet.	R.W.	Rain-water gully trap.
I.C.	Inspection chamber.	B.W.	Bath waste gully trap.	C.E.	Clearing eye or access cover.

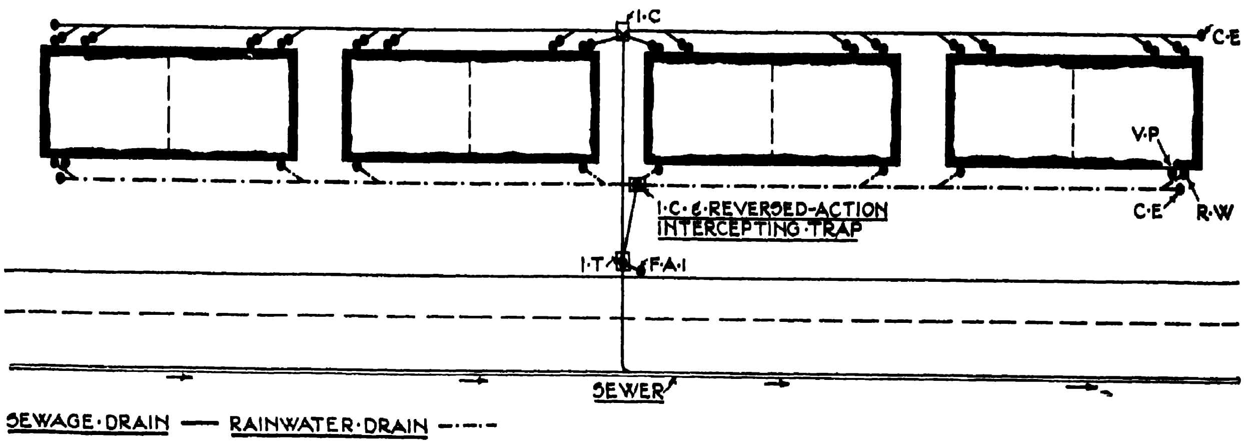


FIG. 248. Plan of combined drain for eight houses. Drain and branch drains furnished with means of access. Rain-water drain at front of houses ventilated and discharging into inspection chamber with reversed-action intercepting trap.

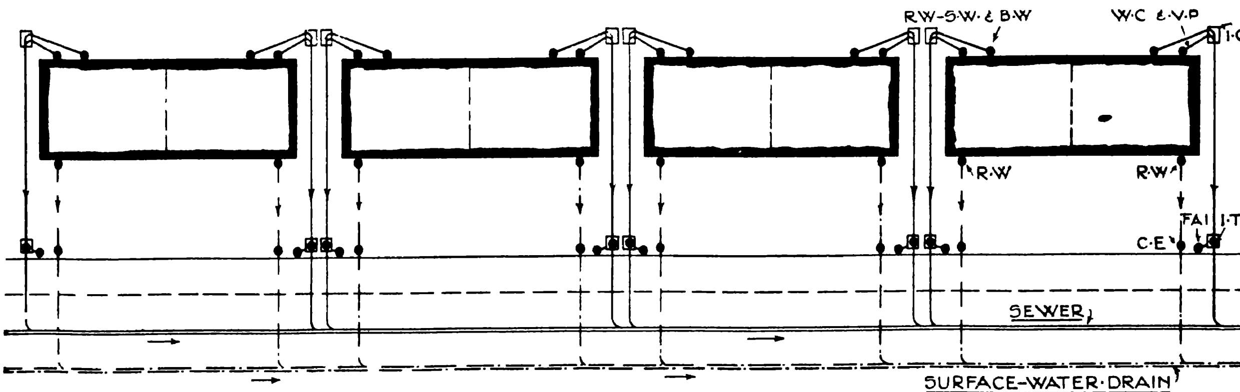


FIG. 249. Plan of drainage for eight houses with separate sewage and surface-water drains for each house. Surface water at rear discharging into sewage drain.

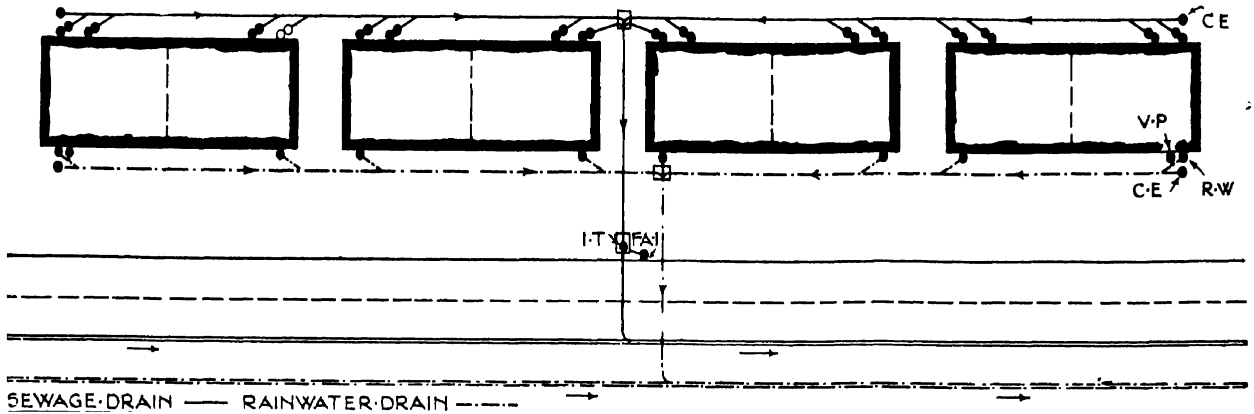


FIG. 250. Plan of combined drains for eight houses discharging to (*a*) sewer, and (*b*) surface-water drain. Surface water at rear discharging into sewage drain.

may percolate through the subsoil; a 'surface-water' drain as a drain used or constructed to be used solely for conveying to any sewer (either directly or through another drain) any rain-water from roofs and from ground surfaces whether paved or unpaved; and a 'sewage' drain as a drain used or constructed to be used for conveying solid or liquid waste matters to a sewer, including such portions of drains as are used for conveying rain-water or surface-water to a sewage drain without the intervention of a trap.[1]

A broader interpretation would construe subsoil and surface-water drains as those used for the stated purposes without regard to the outlet or discharging point, and a sewage drain as one conveying foul waste matters to a sewer, cesspool, or sewage-disposal works.

Disposal of Subsoil- and Surface-water

Where a surface-water sewer is available a satisfactory outlet is afforded. In rural and rural-urban localities if the soil is of gravel, chalk, or other porous substance, subsoil- and surface-water may be run into dumbwells or soakaways, which, to avoid dampness, should be not less than 10 ft. distant from buildings; or into an open or covered-in ditch, or a watercourse. In boroughs and other areas where such methods are unattainable the only mode of discharge is to a sewage drain or a sewer conveying sewage.

Subsoil Drains

These should consist of unjointed field or agricultural pipes, or perforated or half-socketed glazed stoneware pipes,[2] laid in prepared trenches and covered by not less than 6 in. of gravel or hardcore to minimize the carriage of soil into the pipes by the infiltrating water. The drains

[1] See footnote on p. 210.

[2] The Model code, Urban, Series IV, 1925, specifies 'earthenware field pipes or other suitable pipes properly laid to a suitable outfall'. Identical materials are specified in the Drainage By-laws made under the Metropolis Management Acts of 1855 and 1899.

should be laid in straight lines, with an inspection or access chamber at the outfall, whether the latter is to a soakaway, ditch, sewage drain, or sewer taking either surface-water or sewage.

If the drain consists of stoneware pipes a small access chamber or an access pipe at the highest end of each drain will provide for 'rodding' or clearing should a stoppage occur. If field pipes are used, 'rodding' is difficult owing to the greater liability of such pipes to settle out of line.

Where connexion to a sewage drain is necessary an intercepting trap should be provided furnished with a ventilating opening as close as practicable to the trap, and the drain between the trap and the sewage drain or sewer constructed as a sewage drain,[1] but such connexion should be avoided if possible owing to the risk of the intercepting trap becoming unsealed during dry weather, in which case foul air can find its way into the subsoil drain. To maintain the seal, waste water from a fitment should, if practicable, be arranged to discharge into the trap.

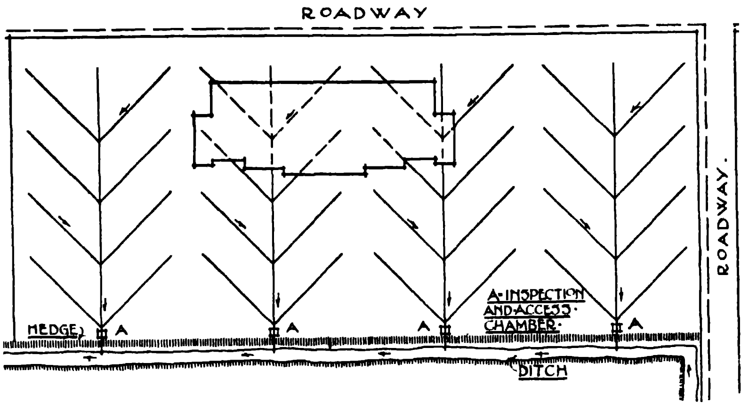
Should the depth of the lowest end of the drain make it impracticable to discharge into an outfall drain or sewer of any kind and the soil be so impervious or the water-level so high as to void the use of a soakaway, it may be necessary to drain to a sump and lift the infiltrated water, by means of a pump—hand-worked or power-driven—or a sewage lift of the type mentioned on p. 389, to a level where the water can be discharged into an outfall drain or sewer. For deep-level basement sites an installation of this character is sometimes requisite.

Figs. 251, 252, 253, and 254 respectively illustrate a plan of drainage to a ditch, an access chamber, drains discharging to a sewage drain, and a plan and section showing the discharge to a trap on a sewage drain.

[1] These requirements are compulsory in London boroughs. Under the Model by-laws (Urban, Series IV, 1925) a subsoil drain must not discharge into a sewage drain, sewer, or cesspool if any other means of disposal is reasonably available. If so discharging, a disconnecting trap and means of ventilation are necessary.

Surface-water Drains

These may be separated into three classes, viz., drains discharging to (1) a soakaway or ditch, (2) a surface-water sewer, and (3) a sewage drain or sewer.



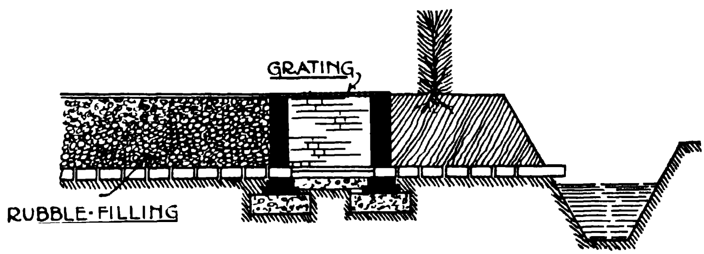
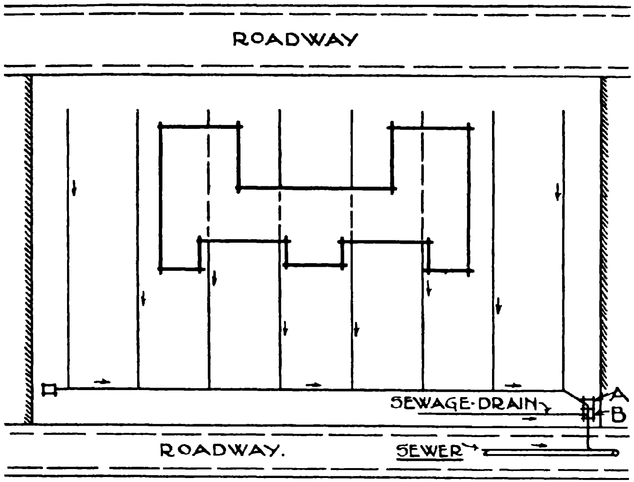


FIG. 251 (*above*). A system of subsoil drains discharging to ditch.
FIG. 252 (*below*). Enlarged detail of access chambers (Fig. 251).

For (1) the pipes should be of the same materials, jointed and laid as sewage drains, but the inlets can take the form of trapless gullies (Fig. 124, Chapter XIII, p. 234) and thus provide for ventilation. Ample access is necessary and may be provided by an inspection chamber at the lowest end of drain, inspection bends and junctions with small access chambers, wide-mouthed trapless gullies and gully traps fitted with clearing eyes or access caps. To prevent the use of the system as a rat-run all trapless



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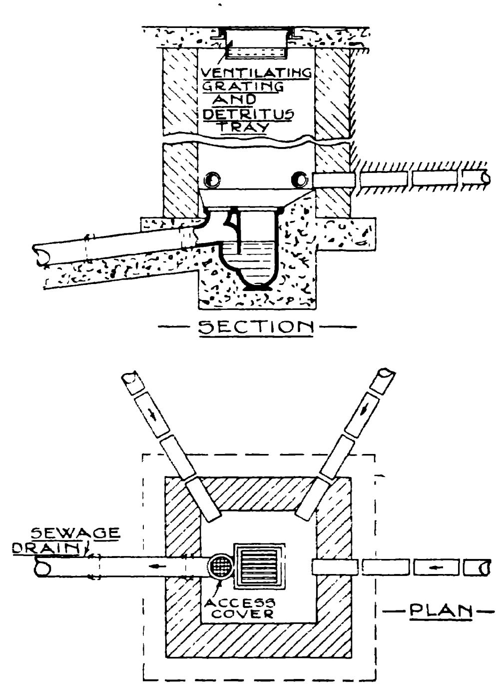

254

FIG. 253. Plan of subsoil drains discharging into sewage drain.

A. Access and intercepting chamber.

B. Sewage drain inspection chamber.

FIG. 254. Plan and section of chamber and trap for intercepting subsoil drains from sewage drain.

gullies should be fitted with locking grids, and the outlet protected by a grating removable for access. An intercepting trap between soakaway or ditch is unnecessary.

The form of construction for (2) should be the same as a sewage drain, except that trapless gullies fitted with locking grids may be fixed at the inlets and an intercepting trap omitted; always provided that trapped inlets and an intercepting trap are not compulsory under the local by-laws. If the inlets are trapped, provision for ventilation is needed.

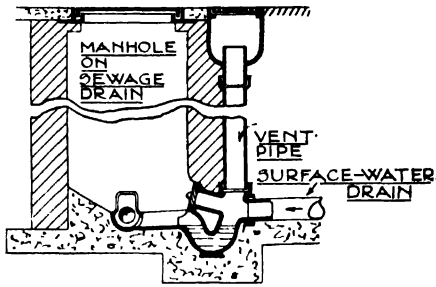

FIG. 255. Inspection chamber with reverse-action intercepting trap between surface-water and sewage drains and means of ventilation to surface-water drain.

For (3) the construction should coincide with the detailed requirements for a sewage drain,[1] except that any inlet not less than 10 ft. distant from a building, or receiving rain-water only, may be in the form of a trapless gully if such drain discharges into a proper trap. In many situations rain-water drains below ground can be avoided by the use of surface channels leading to a gully.

Extensive drainage systems can be sectionized so that surface-water drains are aerially disconnected from the portions conveying sewage by a reverse-action intercepting trap (Fig. 118, Chapter XIII, p. 231) fixed in an inspection chamber (in which position a trap is least likely to have its seal affected by evaporation in dry weather) and separately ventilated (Fig. 255).

If drains intended for conveying surface-water are used for foul-water discharges the inlets should be trapped. Traps on surface-water drains, particularly those at the

[1] See footnote on p. 210. The Model by-laws, Urban, Series IV, 1925, specify compliance with certain of the requirements appertaining to sewage drains.

ground-level, are subject to unsealing in dry weather by evaporation of the contents, and it is consequently advantageous to connect rain-water pipes and surface-water drains to a gully trap receiving a discharge from a waste

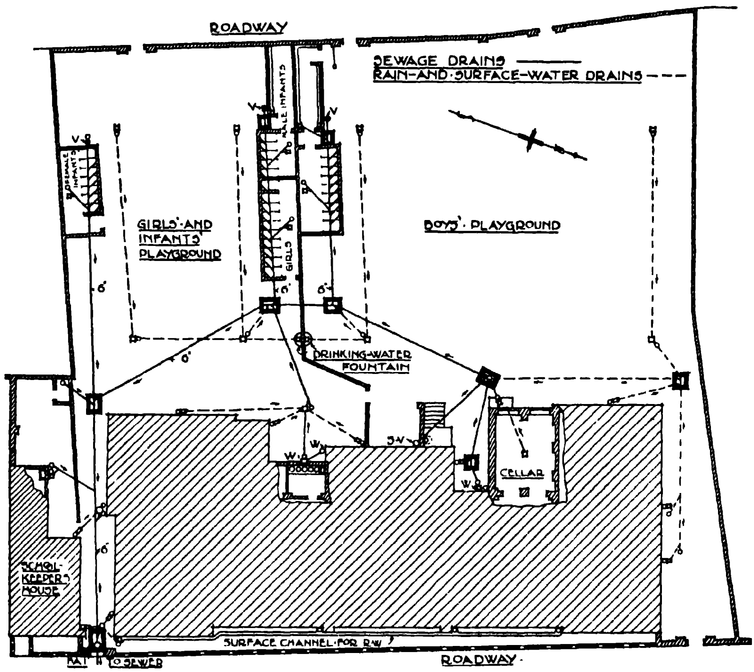

FIG. 256. Plan of drainage for a 'town' school: combined system.

fitment. As a precaution, periodic flushing and recharging of all surface traps is desirable. Fig. 256 illustrates a sectionized drain.

Fall for Subsoil and Surface-water Drains

It is sometimes asserted that as these drains merely convey water a fall much less than that given to sewage drains is sufficient. It must not, however, be lost sight of that where soil is carried into the former through the open joints and into the latter at the inlets, unless the fall is sufficient to allow for its removal by the flowing water,

silting up will take place. Table No. XV (Chapter XVI, p. 300) is based on the least velocities required to keep pipes free from deposit, and therefore the falls or gradients therein given should be adhered to for subsoil and surface-water drains where much solid matter is conveyed. A fall giving a greater velocity than 5 ft. per second is inadvisable owing to the scouring and wearing effect on the pipes of the water-borne debris.

Sewage Drains

By-law requirements may be scheduled as:[1]

(1) *Materials.*—Cast-iron, stoneware, or other equally suitable material.

(2) *Size and fall.*—Of a suitable size, a minimum internal diameter of 4 in. and laid to a suitable fall.

(3) *Joints and jointing substances.*—Cast-iron pipes, socketed joints caulked with metallic lead, or flanged joints bolted together with a suitable insertion; socketed joints for stoneware pipes and pipes of other materials than metal made with Portland cement.

(4) *Laying in external positions.*—On bed of cement concrete not less than 6 in. thick and 12 in. wider than the external diameter of the pipe, haunched up to not less than half the external diameter of the pipe.

(5) *Junctions.*—Branch drain to join another drain obliquely in the direction of the flow and as near as practicable to the invert.

(6) *Drains within or under buildings.*—Only where any other mode is impracticable; pipes laid or fixed in a direct line and provided with adequate means of access at each end; if of stoneware encased in concrete at least 6 in. thick; if of cast-iron on bed as provided in (4); if of cast-iron above ground, carried on adequate piers or other supports at each joint.

(7) *Protection of drain beneath wall.*—By a relieving arch or other support not bearing on the drain.

(8) *Inlets within buildings.*—Only inlets from any water-closet, slop-sink, or urinal. Other inlets prohibited unless external position is impracticable. If provided within a building, inlet must have

[1] See footnote on p. 210.

a suitable and efficient trap having a suitable screwed or bolted air-tight cover and adequate means of ventilation to the external air.

(9) *Trapping of inlets.* (See Chapter XII, p. 210.)

(10) *Interception from sewer.* (See Chapter XII, p. 213.)

(11) *Access.*—Every means to be fitted with a suitable cover; if within or under a building, furnished with a suitable screwed or bolted air-tight cover fixed, in the case of a manhole, to the channel of the manhole.

(12) *Water-tightness.*—Drain to be water-tight and capable of withstanding a minimum pressure of 2 ft. head of water; means of access to be water-tight.

(13) *Ventilation.* (See Chapter XII, p. 220.)

Drain-ventilating pipes to have a minimum internal diameter of $3\frac{1}{2}$ in. fixed without unnecessary bends or angles and constructed as a soil or soil-ventilating pipe; open end of pipe to be fitted with a protective grating or cover with apertures not less than the sectional area of the pipe. Soil and soil-ventilating pipes and waste and ventilating pipes of slop-sinks or urinals, when position and sectional area meet the above-mentioned requirements, may be utilized as drain-ventilating pipes.

(14) *Rain-water pipes.*—To discharge into a surface-water drain, or directly or by means of a channel into or over a properly trapped gully or other suitable trap connected to a sewage drain above the level of the water in such trap.

This schedule summarizes both principles and details of modern drain construction, and although relating only to drains connecting with sewers should be held to apply to drains communicating with cesspools or other places for the reception of sewage.

Many of the details are referred to in Chapters XII to XVI and need no further comment. Reference may now be made to details not previously mentioned and to other items of interest.

Iron *v.* Stoneware Drains

Iron drains are preferable to stoneware except where the discharges are of a chemical nature causing corrosion

of the iron, as they are stronger, have fewer joints, and are much more likely to remain in a gas- and water-tight condition. Their cost is not greatly in excess of stoneware.

Cement and Concrete for Drainage Work

Cement should be Portland cement of the best quality; and concrete a composition of clean gravel, hard brick broken small or other similar hard and suitable aggregate, with a sufficient quantity of clean sand, well mixed with cement in the proportion of not less than one part by measure of cement to eight parts of other material.

Planning

All drains should be laid in straight lines between points of inspection. Branch drains conveying sewage from a soil pipe or a waste pipe from other soil fitments, or a single drain inlet trap, may be connected direct to a main drain, if an inspection eye is provided at the base of the soil- or waste-pipe or to the gully trap and the junction is furnished with an access cover; but fitments in groups are easier of access if connected separately to an inspection chamber. Long lengths of unventilated drains should be avoided. To secure adequate ventilation on extensive systems the drains may be sectionized as in Fig. 255 by using reverse-action intercepting traps.

In Fig. 256 is given a plan of a sectionized combined system of drainage for a town school.

Drains within or under Buildings

Whether laid below ground, above ground on piers or other supports, fixed against walls, or suspended beneath floors, these should without exception be constructed in iron, a form which can be insisted upon by the sanitary authority. Inspection chambers and drain inlets, if practicable, ought to be outside the external walls; if provided within or under a building they should have sealed covers

(Figs. 107 and 139, Chapter XIII, pp. 227 and 240) and adequate means of ventilation to the external air.

Inlets in places where food is stored or prepared and in such places as dairies and cow-sheds are indefensible and in some areas are prohibited.[1] Where floor drainage is requisite surface channels should be formed leading to a drain inlet outside the external walls.

Drains external to Buildings

If above ground, iron should be used; below ground, either iron or stoneware, preference being given to iron for the reasons stated above.

Means of Access

A branch drain taking the discharge from a gully trap may be made accessible by means of an inspection eye forming part of the trap (Fig. 109); a drain from the base of a soil pipe by a shoe with access cover (Fig. 126); a ventilating pipe by a rust pocket fitted with an access cover (Fig. 125); a straight run of drain by a bend or sweeping arm carried to the ground-level and fitted with a sealed cover or cap; a bend in the course of the drain and the junction of a branch and main drain by inspection covers (Figs. 133 and 134); and a number of connexions assembled in one spot by a self-contained chamber with sealed cover (Fig. 139), or open channel and channel bends in a chamber in aerial communication with the drain (Fig. 257). An intercepting trap may form part of a sealed system, or be fitted in an open chamber, in either case access to the drain between trap and sewer or cesspool being given by a raking arm with sealed cap.

Open *v.* Closed Channels in Inspection Chambers

Compared with closed or sealed channels, open channels are objectionable as they permit (1) fouling of the chamber, (2) submersion of the cover to raking arm of

[1] See Chapter IX, p. 162.

intercepting trap on a temporary stoppage of the drain, (3) accumulation of foul air in the chamber, and (4) necessitate a chamber both gas- and water-tight.

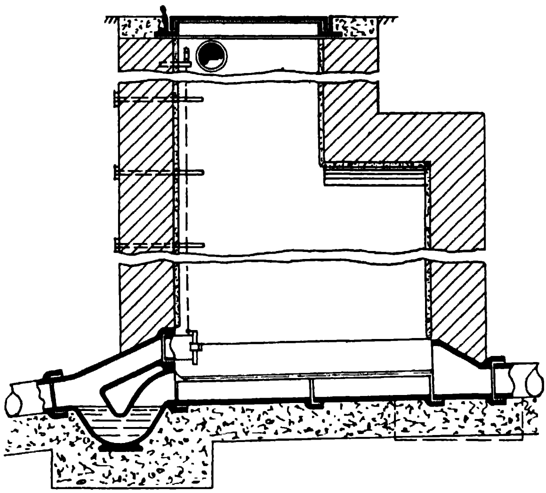

FIG. 257. Section of inspection chamber with intercepting trap and open channel.

Inspection Chambers

Chambers (Fig. 257) with open channels should be constructed of brickwork or concrete with concrete benchings, with the internal surfaces rendered in Portland cement trowelled smooth, finished so as to be water-tight up to the ground-level, and fitted with a cast-iron air-tight cover. Chambers with sealed channels should be substantially constructed of like materials, properly benched and rendered, but water-tightness need not be insisted upon nor emphasis laid on the air-tightness of the cover.

The thickness of the walls and the size of the chamber respectively must be regulated by the depth and the number of branch connexions. The space provided ought to allow sufficient man-room for 'rodding'. For deep chambers the minimum internal plan measurements may be put at 3 ft. 6 in. × 2 ft. 6 in., and if over 3 ft. deep, cast-iron coated or galvanized step-irons should be built into side 18 in. apart.

Flushing of Drains

Sewage drains laid to the falls suggested in Table No. XV, Chapter XVI, p. 300, seldom require special flushing arrangements. If, however, the fall is insufficient, or much solid or greasy matter is discharged thereto, additional means of flushing, such as an automatic cistern of a capacity up to 30 gal., discharging into an ordinary trapped gully or flush-out grease trap is generally effectual. Foul waste water is sometimes collected in a flushing tank fitted with a siphonic discharge, but a fitting of this kind is likely to cause offence and therefore its provision close to an occupied building is not advocated; if provided, the tank should be fixed in a chamber with air-tight cover.

Drainage of Buildings with Basements below Sewer-level

The provision necessary for the drainage of buildings having one or more floors below the level of the available sewer is of a special character involving the use of sewage-raising appliances. Where it is practicable to locate all the soil- and waste-fitments on floors allowing drainage by gravitation this should be done, as it then leaves only surface and / or subsoil water to be raised by mechanical means. If this is not possible in its entirety, waste matters and water above the sewer-level should be led to a point where gravitation to the sewer can be had, leaving the sewage matters from the soil fitments below the sewer-level with any subsoil- or surface-water to be lifted mechanically. Failing such division, the whole of the sewage with any subsoil- and surface-water can be discharged to a sump or chamber and then lifted by a pump or ejector to a height whence gravitation to the sewer is assured.

Of the available lifting appliances, electrically-driven pumps and ejectors worked by air-compression are often used. To prevent flooding the operation should, without

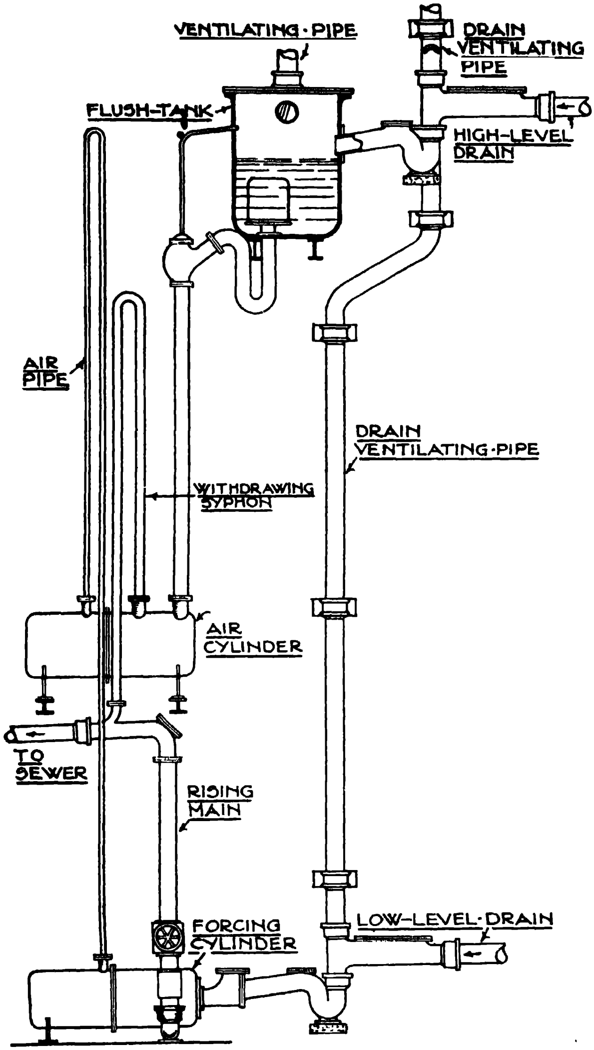

FIG. 258. Diagram showing Adams's patent automatic sewage lift (the 'Autaram') for raising low-level sewage by high-level sewage in connexion with a sealed system of drainage.

exception, be automatic. A pump installation can be so arranged that the motor is respectively started and stopped by the rise and fall of a float on the surface of the sewage

or water in the sump or chamber. The objection to such mechanical devices is the liability of the pump and motor to get out of order.

Fig. 258 illustrates Adams's Patent 'Autaram' sewage lift by means of which high-level sewage is utilized for raising low-level sewage. Here the high-level sewage gravitates into an automatic siphonic flush-tank which discharges to an air-cylinder, drives out the air from the latter to the forcing cylinder into which sewage has entered from the low-level drain, and ejects the sewage up the rising main to the sewer, the sewage in the air-cylinder being withdrawn through a siphon pipe after the discharge of the flush-tank. The drawback to this apparatus is its limited sewage lift, at least 2 ft. head being required for every foot lifted.

Where a supply of high-level sewage is not available the apparatus can be worked by a supply of water from a storage cistern, the water operating the lift being afterwards discharged to a storage cistern for flushing sanitary conveniences, &c. These automatic lifts are practically fool-proof, can be attended to by an unskilled person, and are economical in maintenance and working.

Where power is available for a compressed-air plant the ejector shown in Fig. 259 can be used advantageously, the height of lift being almost immaterial, for apparatus are in operation raising sewage to a height of 120 ft.

Where any such installation is directly associated with an occupied building, the inspection and plant chambers should be placed either in an open area, or a cellar approached from an open area and freely ventilated to the external air. If of necessity placed within a building, the drains leading to and from the ejector plant should be of the 'closed' type in cast-iron with the access chambers in an apartment aerially separated from the remainder of the building and with adequate means of ventilation to the external air.

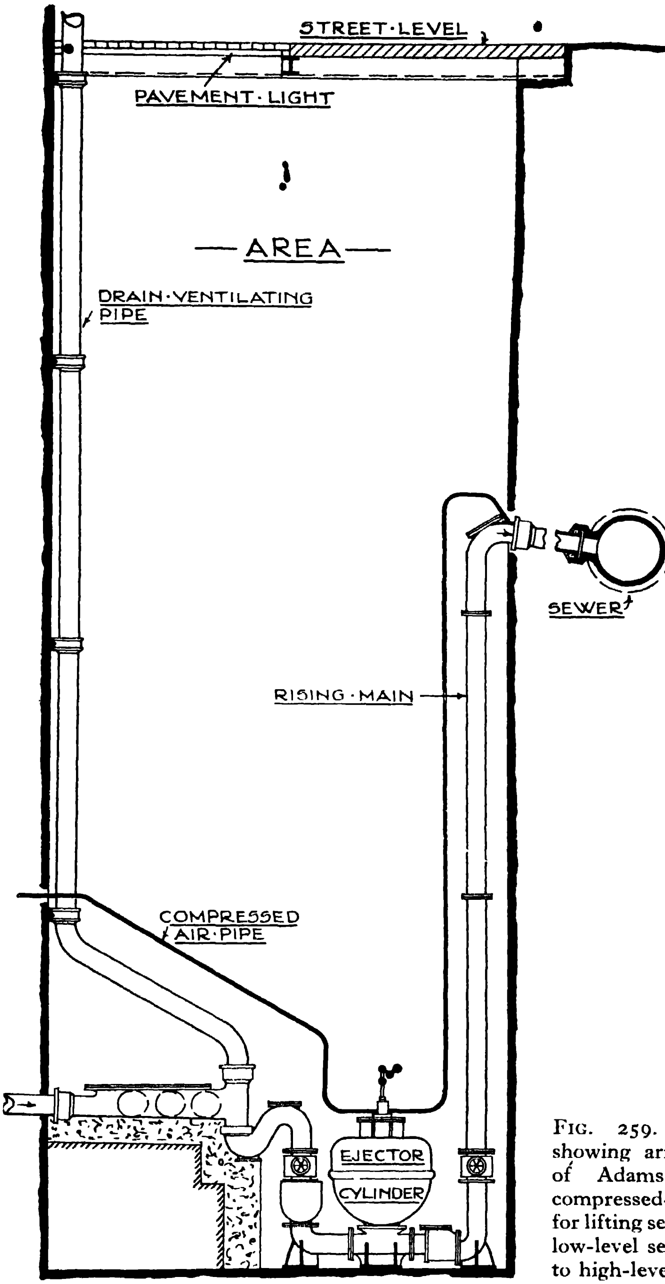

FIG. 259. Diagram showing arrangement of Adams's patent compressed-air ejector for lifting sewage from low-level sealed drain to high-level sewer.

Drainage of Petrol Stores and Garages

The discharge of carbide of calcium, or petroleum spirit (i.e. crude petroleum, oil made from petroleum, coal, shale, peat and other bituminous substances, and any products of petroleum and mixtures containing petroleum giving off an inflammable vapour at a temperature of less than 73° F.) into a sewer or communicating drain is prohibited by statute.[1] Regulations made under the Petroleum Acts, 1871–81, may require an intercepting trap or chamber of approved pattern (see Fig. 116, Chapter XIII) and prohibit the drainage of inspection pits unless the drain passes to such an interceptor.

Improper Construction, Misuse, and Maintenance of Drains

It is an offence to construct or repair drains in an improper manner or in such form as not to be in accord with any by-laws governing such construction.[2] In London it is also an offence to wilfully destroy, damage, interfere with, or improperly use any drain or any water-supply connected therewith so as to create a nuisance or injury to health.[3]

The by-laws in many districts veto any alteration, reconstruction, or repair of any drainage work constructed in accordance with the by-laws in such manner as to allow the alteration, &c., not to be in conformity; require all alterations, reconstructions, and repairs to be carried out, as far as practicable, so as to comply with the by-laws; and place a responsibility upon the owner to maintain all drainage work in a proper state of repair and in proper working order.

[1] The London County Council (General Powers) Act, 1927, and the Public Health Act, 1925.

[2] The Metropolis Management Act, 1855, the Public Health (London) Act, 1891, and the Public Health Act, 1925.

[3] The Public Health (London) Act, 1891.

XXII

SEWAGE PURIFICATION AND DISPOSAL: CONSERVANCY METHODS, CESSPOOLS, DISCHARGE INTO STREAMS, ETC.

THE disposal of sewage from a building is an easy proposition where drainage is effected to a sewer leading to publicly owned sewage-disposal works; but where such facilities are non-existent disposal with dispatch and without causing nuisance presents many difficulties. The construction and working of an installation for disposing of the sewage yielded by a town or other large centre of population is outside the scope of this book, and the methods referred to are considered only from the standpoint of their applicability to an isolated building or group of buildings where a public sewer is not available for the disposal of the waste matters.

Town sewage varies enormously in its composition owing to inconstancy in the volume of water, the percentage of solid matters, and the mixing of trade effluents. Waste matters from individual premises show less inconstancy in volume and constituents, and may be so separated into innocuous, domestic, and trade waste as to facilitate disposal by the least expensive and most effectual methods.

From the aspect of disposal by means of a private installation sewage may be classified as: (1) rain-water; (2) trade effluents; (3) faecal matter (solid and liquid) and water fouled by domestic use. In the minds of some persons a distinction is drawn between water fouled by domestic use, i.e. waste water from cooking, ablutions, washing of utensils and clothes, the cleansing of premises, &c.—sometimes designated '*sullage*'—and excretal matter, the latter only being described as sewage. This distinction is not substantiated by fact, for waste water resulting

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from the named operations contains organic matter subject to decomposition and the production of effluvium nuisance. Such waste water is, and should be treated as, sewage.

Separation of Rain-water and Innocuous Trade Effluents from Sewage

As mentioned in Chapter XXI, p. 368, where the discharge is to a sewer the determination as to whether rain-water should be separated from sewage turns mainly upon whether the provision made for removal is in the form of a single or separate sewers. No such doubt exists where disposal must take place on or in sole connexion with the premises receiving rain-water or yielding waste matters, for it is always desirable that rain-water—whether direct from roofs or from paved or unpaved ground-surfaces—and waste water from the cleansing of paved surfaces, the washing of cars, &c., and from trade processes which do not cause pollution of the used water by the addition of chemical or decomposable animal matter, should be separated from sewage so as to reduce to a minimum the volume of the latter to be treated in the course of disposal.

Disposal of Rain-water

By a careful arrangement of drainage the rain-water can be kept out of the sewage system and discharged to a watercourse, ditch, or soakaway, or to a storage tank where it is necessary to conserve the water for domestic use or where it can be advantageously utilized for garden or general agricultural purposes.

Disposal of Washings from Garages, Petrol Stores, and Trade Premises

The disposal of washings charged with petrol or oil should be closely scrutinized. As suggested in Chapter XXI, p. 392, intercepting traps or chambers are required, and on no account should such washings be discharged direct to a system of drainage conveying rain-water to

storage tanks, a ditch, or watercourse. The best way of disposal is to a specially formed dumb-well or soakaway located where no possibility exists of fouling either surface or underground water-supplies. If this is impracticable on account of the non-porous character of the soil, then the washings should be passed through an efficient trap or catchpit prior to discharge into a ditch or watercourse. It is equally important that such washings should not be discharged into a sewage system leading to disposal works based on the action of bacteria, for the oil will clog the filtering media and both the oil and petrol interfere with the purification of the sewage.

Trade effluents, if innocuous, may be discharged direct to streams or other watercourses, with the provision of straining chambers where necessary to prevent the discharge of detritus which might silt up or otherwise adversely affect the water channel. If treatment is essential prior to discharge at the outfall it is advisable to provide a special installation distinct from that used for the domestic sewage if the latter is to be purified by bacterial means, as the chemical constituents of the effluent may seriously affect the purification process.

Composition of Sewage

Eliminating rain-water and the waste liquids above mentioned, sewage consists of solid and liquid excreta from soil fitments and fouled water from waste-water fitments. Sewage solids may be classed as solids in solution and in suspension, both partly organic and inorganic, and colloids almost wholly organic in composition. Bacteria abound[1] in sewage—chiefly organisms whose activities under favourable conditions result in the decomposition, liquefaction, and oxidation of the sewage, as seen in complete processes of bacterial purification. Pathogenic

[1] Crude sewage usually contains at least one million bacteria per c.c., and not uncommonly more than ten millions. Vide *Royal Commission on Sewage Disposal*, Second Report, 1902, p. 26.

organisms are also present, but in general their existence would not appear to be long sustained in the biological struggle.[1] It has been aptly expressed that 'sewage contains in itself the active agents required for its purification'.[2] The most important chemical constituents of excreta are carbon, nitrogen, hydrogen, and oxygen, with small quantities of phosphorus and sulphur. Solid excreta, if dry, are not notably offensive, but if wet (as when newly deposited) and particularly if mixed with urine, rapid fermentation and decomposition ensues, with the evolution of offensive gases.

Sewage from manufacturing premises may be a domestic sewage from soil and waste fitments mixed with a trade effluent, or solely waste liquids from manufacturing processes; in either case possessing characteristics widely differing from domestic sewage and needing maybe special treatment before discharge to disposal works. The constituent conditions are variable, need individual consideration, and possibly a form of treatment determinable only after expert investigation.

The principal gases evolved from sewage on decomposition are marsh gas, carbon dioxide, and sulphuretted hydrogen, which, with various vapours, produce the odour so noticeably a concomitant of sewers and drains. To avoid nuisance the originating matters should either be finally disposed of before fermentation and decomposition commences, which is often impracticable, or the removal and disposal so surrounded by safeguards as to allow for atmospheric diffusion in a safe position of any offensive gases evolved.

Volume of Sewage to be disposed of

In the absence of complete information as to the actual

[1] *Hygiene and Public Health*, Whitelegge and Newman, p. 263. The reduction is most marked with a filtrated effluent passed through a 4-ft. depth of soil at a slow rate. Effluents from septic tanks and contact beds are nearly as pathogenic as crude sewage. Vide *Royal Commission on Sewage Disposal*. Second Report, 1902, p. 26.

[2] *Sewage Purification and Disposal*, Kershaw, p. 42.

maximum daily volume of sewage to be disposed of—data only ascertained by a series of measurements over a long period and rarely obtainable—the volume may be based on an estimated daily flow, the unit factors being the number of persons in residence or normally using the premises and the consequential daily yield of excretal matter, plus the average daily water-supply.

The amount of excreta yielded per person per diem is variously estimated. Wilson estimated[1] for a male adult 4·17 oz. of faeces and 46·01 oz. of urine; whilst for an average of all ages in an ordinary population Whitelegge and Newman[2] give 2½ oz. of solid excreta and 40 oz. of urine. Ghosh and Das state[3] that an adult Indian passes daily about 8 oz. of solid. In India water is used for ablutionary purposes instead of paper, and this water with the liquid excreta amounts to about 80 oz. To such excretal matters must be added the domestic water-supply —a volume showing extreme differences and largely dependent upon the method of supply, the habits of the occupants, and the description of the sanitary arrangements.

In places where the water-supply is derived from a local well or other source where it has to be conveyed by hand the volume utilized is at the minimum, probably not exceeding 10 gallons per head per day. *Per contra*, when derived from a public supply the consumption may be anything up to 60 gallons or even more per head per day.

For houses having neither baths nor water-closets 12 gallons may be taken as the minimum average supply necessary, and 25 gallons where baths and water-closets are provided.[4] In hospitals and institutions the supply per head may be put at 50 gallons, at day-schools 10 gallons per person, and for horses 15 gallons each. The

[1] *Handbook of Hygiene*, p. 339.
[2] *Hygiene and Public Health*, p. 262. [3] *Hygiene and Public Health*, p. 183.
[4] *A Treatise on Hygiene and Public Health*, Stevenson and Murphy, p. 244.

minimum supply for India is estimated by Ghosh and Das[1] at 30 gallons during the wet season and a quantity much above this figure in summer.

If the town supply is accepted as the basis of computation a sufficient margin is allowed to meet an emergency call upon the method of disposal, for with, say, 40 gallons per head per day it may safely be assumed that 10 gallons of this is absorbed by various public services, such as flushing of sewers, street watering, &c.

As an example, a building having 250 occupants may be taken. Here, on the figures just given, the daily yield of sewage would approximate to:

Excreta—Solids	2·5 oz.	
Urine	40·0 oz.	
	42·5 oz. × 250 =	66·0 gal.
Water-supply—40 gal.	× 250 =	10,000·0 gal.
		10,066·0 gal.

In round figures 10,000 gallons.

The importance of excluding rain-water from the sewage to undergo treatment is herewith strikingly illustrated, for the volume given above will be the dry-weather flow (D.W.F.), and an allowance must be made for the anticipated rainfall—a difference determinable as three to six times that of the D.W.F.[2]

'Dry-earth' or 'Conservancy' Method of Sewage Disposal

This method may briefly be described as the conversion of crude excreta derived from privies, or crude excreta mixed with earth or other deodorizing substance from earth-closets, into humus (vegetable mould) by the action of bacteria. The conversion is a biological process and,

[1] *Hygiene and Public Health*, p. 2.

[2] The Ministry of Health's requirements for public disposal works specify that two to three times the D.W.F. must be treated as sewage proper, and the provision of storm-water filters for an additional three-times' flow. If storm-water and sewage are treated together upon filters the capacity must equal six times the D.W.F.

therefore, any admixture of an antiseptic, or other substance, or any form of treatment (such as 'stove' drying) which would render the excreta or the soil used therewith sterile must be avoided.

The use of privies and earth-closets predicates a system of removal by hand of the resulting faecal matter or, as commonly described, night-soil, and in the case of earth-closets the provision of a deodorizing substance which materially adds to the bulk to be removed. The details to be observed in the construction and fitting up of these conveniences are enumerated in Chapters XI, p. 190, and XVIII, p. 326.

The contents of old-fashioned privies in pit or midden form are often left undisturbed for long periods and, when removed, stale and fresh excreta are indiscriminately mixed, necessitating a uniform treatment of the whole bulk as fresh or crude excreta. With 'pail' privies and earth-closets frequent removal of the excreta is compulsory owing to the limited size of the receptacles, and the pail contents are always in a condition of actual or probable offence.

In a 'privy' town the removal is commonly undertaken by the sanitary authority, either direct or by arrangement with a contractor, several times a week. Sanitary authorities in London[1] must undertake the emptying and cleansing of earth-closets, privies, and cesspools at stated periods. In areas governed by the Public Health Act, 1875, the Minister of Health can by order put this obligation on the sanitary authority; failing such order the latter may do the work or by by-law put the responsibility upon the occupier of the premises.[2]

The disposal of night-soil from privies and earth-closets abounds in probabilities of nuisance. Left to the occupier of the premises it is often dumped on or scattered over the surface of the ground close to dwellings; removed by the

[1] The Public Health (London) Act, 1891.
[2] The Public Health Act, 1875.

sanitary authority it may be burnt in a destructor or incinerator, but more frequently is dumped on a piece of available land without much discretion, and in some instances close enough to buildings or places of public resort to cause nuisance by smell and flies. Deposited in heaps it constitutes a breeding-place for flies and a harbourage for rats.

Burning in a destructor or incinerator is a sanitary measure if conducted at a distance from occupied buildings and in a properly constructed furnace, but its practicability is largely restricted to the operations of a sanitary authority and to cases where a supply of combustible substances, such as sawdust or wood shavings, is available at small cost. The burning of night-soil in gardens attached to occupied buildings cannot, however, be advocated as it is likely to result in offence.

Methods which may safely be adopted for disposal without nuisance are:

(1) *Shallow trenching*.—This can be made effective in any location where sufficient cultivatable land exists. The situation of the selected site should be high or well-drained and the soil dry and porous, humus and light sandy loam being the most, and water-retaining clay the least, satisfactory. Trenches should be dug not less than 1 ft. apart, and not more than 2 ft. in width and depth. The trench should be filled about a third of the depth with night-soil and covered with the dug-out soil.

The time taken for the biological humification of the buried excreta varies with the nature of the soil, the time of year, climate, and other factors; it is most rapid in showery summer weather as the warmth and moisture facilitates the growth of the necessary bacteria. Poore[1] put the period of accomplishment from three weeks to three months according to the climatic conditions. The process is accelerated by cultivation of the land as vegetation partly absorbs the sewage, evaporates moisture,

[1] *Rural Hygiene*, pp. 202 and 204.

assists oxygenation of the soil, and thus prevents sewage sickness of the latter. According to Das[1] it is safe to retrench ground thus used every six or seven months, for, as experienced in India, examination of the buried excreta at the end of such periods disclosed that they had been transformed into a sort of loose black earth with no trace or odour of faecal matter. As showing the possibility of re-using time after time the site for this form of disposal, Das also found that in a '*ripe* or repeatedly trenched soil it took nearly five, but never less than four months, for such a change to take place, irrespective of weather conditions, whereas with a *virgin* soil it took about three months more for the excreta to acquire this character'.[2]

(2) *Deep trenching*.—Where an area adequate for the method just described does not exist a pit several feet in depth can be dug in a porous soil and gradually filled up with 3- to 4-in. layers of excreta and 9-in. covering layers of soil, the latter being sufficient to prevent effluvia and fly-breeding. Subsoil below 3 ft. from the surface tends to bacterial sterility; hence humification is much slower. The process in the bottom layers is also slowed down as they are unaffected by the cultivation of the surface soil. Deep trenching *disposes* of the night-soil, but the method is less effective as a purification process than shallow trenching.

With excreta buried in either shallow or deep trenches a liability exists of ground-air emanations of somewhat offensive character. The selected site should consequently be as far distant as practicable from occupied buildings. One hundred feet is suggested as the minimum. The position chosen should also be such that there is no possibility of surface or underground streams utilizable for drinking-water supplies being affected.

(3) *Stacking and drying*.—Excreta mixed with humus

[1] 'A few observations on the trenching of Night-soil', Dr. Jahar Lal Das, *Journal of the Royal Sanitary Institute*, November 1922, p. 133.
[2] Ibid.

removed from earth-closets, if stored dry in an open shed situated well away from an occupied building and turned over from time to time, lose all their offensive properties and can be re-used again and again, the enrichment with humus increasing with re-use and bringing about quicker humification of the fresh or crude excreta.

'Conservancy' Methods *v.* 'Water-carriage' Systems

Privies and trench latrines can in particular circumstances and under special control be justified for temporary usage in camps, fairs, &c., and for the use of village communities in countries where water-supplies are inadequate and a better type of convenience is unattainable, but in rural and urban areas generally there is no justification for their provision.

Earth-closets can be accepted in rural or isolated areas for premises without a reasonable supply of water for flushing purposes, e.g. where the supply is restricted to that obtained from a well by a hand-worked pump, so long as adequate facilities exist for obtaining sufficient suitable deodorizing substances and disposing of excreta, but in urban or crowded areas where such facilities are lacking their provision is indefensible. If a supply of water is not laid on to the premises it is better to instal a waste-water closet of the type shown by Fig. 188 (Chapter XVII, p. 313), and connect to the drainage system intended for the reception of waste water.

The fact that a 'conservancy' method is not capable of removing and disposing of liquid excreta and fouled water is in itself a sufficient argument for favouring a water-carriage system and the installation of disposal works capable of dealing with *all* the sewage. Further, the retention of uncovered or but partly covered faecal matter near occupied buildings provides a nidus for the breeding of flies and permits conveyance by them of filth and infective matter on to food-stuffs.

There is much truth in the dictum expressed by Cor-

field some fifty years ago[1] that a well-managed dry-earth conservancy system is better than no system at all, but 'we do not want conservancy at all; our first object must be to get rid of refuse-matters, and not to see how long we can keep them about our houses in a *presumed* harmless condition'.

Disposal of Slop-water

The great weakness of the 'conservancy' method is the inability to deal with liquid sewage. Effectiveness hinges to no small extent upon the dryness of the faecal matter, and any excess of urine above the absorptive power of the deodorizing substance militates against the storage and disposal of the excreta without nuisance. Consequently, mixing of bedroom slops or water from waste fitments with excreta is out of the question and other and separate means of disposal are compulsory. In India, where water is used for body cleansing after defecation, the importance of separating solids from liquids is well recognized in the case of privies, the latter commonly being designed so that solid excreta and urine and ablutionary water are deposited in separate receptacles, as in Fig. 260.

Where privies or earth-closets are provided it is not unusual for slop-water to be thrown on the surface of the ground, a practice possibly pardonable if it takes place at a distance from occupied buildings and constant cultivation of the surface soil is assured. The latter, however, is exceptional, and thus an insanitary condition is the common outcome.

The memorandum[2] of the Minister of Health relating to schools in country places states:

'Even where dry closets are provided and rain-water is separately dealt with, there will still be need for some means of disposing of foul waste liquids as from urinals, sinks, lavatory basins, and wash-pails. If sewers are not available these liquids may be taken by

[1] *Treatment and Utilization of Sewage*, Corfield, p. 125.
[2] See footnote 1 on p. 147.

drains to a filter or irrigation area, or into a small cesspool constructed as already mentioned.

'In some instances, where there is no ground belonging to the school sufficient for the placing of a tank or cesspool, it may be necessary to use movable receptacles for the reception of waste liquids from lavatories, urinals, &c., the receptacle for urine being filled with some absorbent such as sawdust. Such expedients, of course, require constant attention—at least daily—if nuisance is to be avoided, and in the case of new schools and, where possible, in all other cases, sufficient ground should be provided to render resort to them unnecessary.

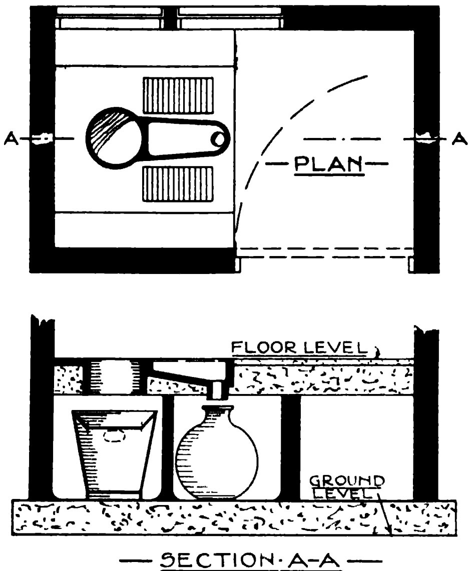


FIG. 260. Plan and section of Eastern privy with separate receptacles for solid and liquid excretal matters.

'Where there is no public water-service, rain-water from the roofs may often be usefully collected for washing purposes, being softer than well-water. Where not so collected, if there is no sewer into which to take it, it should be excluded from the sewage, and may be discharged in any convenient method, as into a ditch or water-course, or, where the soil is porous, into a soakaway pit at a sufficient distance from the building so as not to cause dampness of the foundations.

'Where sewers and public water-service are not available, it is desirable that there should be in connexion with the house plenty of garden ground on which to dispose of refuse matters.'

Disposal is mostly secured by the adoption of one of the following methods. The waste water from sinks and other fitments is run into gully traps connected with a drain

(*a*) having an outfall to a ditch or water-course; (*b*) discharging to a rubble pit or soakaway providing for percolation into and through the subsoil; (*c*) discharging above

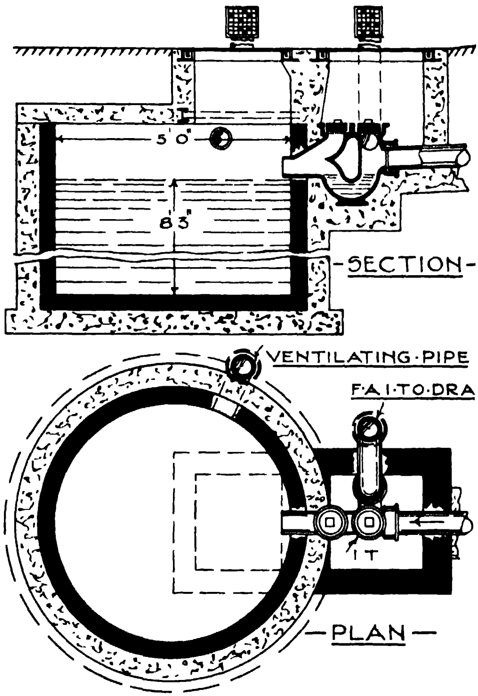


FIG. 261. Plan and section of cesspool lined with cement 'cistern rings' to hold 1,000 gall. with drain intercepting trap and chamber.

the ground-level so as to permit of surface irrigation (Fig. 272); (*d*) with open joints laid about 1 ft. below the surface allowing sub-irrigation or filtration through the subsoil (as at A, Fig. 263); or (*e*) leading to a water-tight cesspool (Fig. 261) from which the sewage is periodically pumped out, utilized as a manure, or removed from the premises for disposal elsewhere.

Discharge of liquid sewage direct to a ditch or water-course should be taboo as fouling and nuisance are inevitable. The soil surrounding a soakaway soon becomes sewage-sodden or sick and non-absorbent, necessitating

periodic removal and replacement by clean earth. A cesspool is not an ideal arrangement, but if water-tight it can in suitable circumstances be worked without much nuisance. Surface- and sub-irrigation may be satisfactory if the site is suitable, the soil porous, and strict attention given respectively to cultivation and the maintenance of the pipe system with a surround of suitable soil. With all these methods grease should be prevented from entering the drain, where it would congeal and clog either the pipe or at the outfall, by using grease-traps of the kind illustrated by Fig. 113 on p. 228.

Percolation of sewage into the subsoil, whether from subsoil drains, soakaways, or non-water-tight cesspools, presents an obvious risk of fouling water-supplies and should only be countenanced where no such risk is possible. If the percolation site is close to buildings there is a danger of soakage under the foundations. In many situations offensive ground-air emanates from the sewage-sick soil, a paramount experience in a district where non-water-tight cesspools are the rule.

Water-carriage Systems of Sewage Removal Coupled with Methods of Disposal and Purification

These can be divided into separate categories: (1) disposal, and (2) purification. The former embrace discharge into (*a*) cesspools, and (*b*) tidal and non-tidal rivers and the sea; and the latter purification by means of (i) broad irrigation, (ii) downward filtration, (iii) chemical precipitation, and (iv) bacterial treatment.

(*a*) *Cesspools.*—These are the commonest form of storage and disposal works in unsewered districts and, unless adequate precautions are taken, are the cause of much effluvium nuisance both during storage and removal of the sewage.

The position and construction should comply with the following requirements:[1]

[1] Based on the by-laws enforceable in London.

1. *Situation*

(*a*) One hundred feet at the least from any public room, any building occupied by any person or in which any person is employed, and any well, spring, or stream of water.

(*b*) In such a position as to afford ready means of access for the purpose of emptying and cleansing such cesspool and for removing the contents therefrom without being carried through any building.

2. *Form of Construction*

(*a*) Of concrete, or good brickwork bedded and grouted in cement and rendered on the inside surface with cement, with walls and floor at least 9 in. in thickness, and so as to be perfectly water-tight.

(*b*) Arched or otherwise properly covered over, and furnished with a suitable air-tight cover for the purpose of access.

(*c*) Provided with adequate means of ventilation.

(*d*) Not in communication with any sewer, nor provided with any overflow outlet.

Fig. 261 illustrates a cesspool of the stipulated construction.

Where cesspools or tanks are constructed to take the drainage from elementary schools it is specified[1] that:

'rain-water should be excluded from the sewage with a view to lessen its volume, and to avoid the need for frequent emptying; walls and floors so constructed as to be quite water-tight; not less than 50 ft. distant from the school or from any dwelling-house, and as far as possible from any well or other underground source of drinking-water which might be in danger of being polluted by leakage; properly ventilated; provided with a suitable pump, and in position conveniently accessible by a tank cart for the purpose of emptying.'

Emphasis should be laid on the necessity of choosing a position as far away from occupied buildings as is reasonably practicable. Many codes of by-laws stipulate but 30 ft.; in practice 100 ft. should be recognized as the minimum intervening distance.[2] Further, the cesspool

[1] See footnote 1 on p. 147.

[2] The Model by-laws (Urban, Series IV, 1925) specify 50 ft. from a dwelling-house, &c., and 60 ft. from a well or other source of water-supply.

should be water-tight so as to prevent soakage into the soil—with the resulting contamination of the soil and the ground-air which eventually mixes with the atmospheric cloak and, possibly, the pollution of water-supplies—and the infiltration of subsoil water. Moreover, the contents should be removed sufficiently often to prevent sewage backing up through the communicating pipes and traps.

The size of the cesspool is seldom prescribed; where prescribed the size is generally based on the number of rooms in the house, e.g. a sliding scale ranging from 750 gallons for 6 rooms to 1,500 gallons for 14 rooms. In some cases the by-laws place on the occupier of the premises the duty of emptying the cesspool at least once in every three months.

A better unit standard than the number of rooms is the number of occupants or users of the premises. If a six-roomed house is occupied by five persons and the sewage yield is 25 gallons per head per day, a water-tight cesspool with a content of 750 gallons would be fully charged in six days. If emptying is by a pump and disposal, as manure, takes place on the premises it is possible to deal with the sewage, provided there is ample garden land and the surface is properly cultivated; but if, as so frequently happens, the sewage must be removed from the premises by the sanitary authority, the cost of the work becomes a serious charge either on the owner, occupier, or the local rates. The consequence is that even where a *water-tight* cesspool is specified, the by-law is either totally ignored or, if adhered to, the cesspool is so altered after construction as to allow percolation of the liquid contents into the subsoil, thus converting it into a soakaway with its inherent objections.

If the removal charge is on the occupier there is often a grave tendency to reduce the expense by throwing slop-water and baled or pumped-out sewage from the cesspool on to the surface of the open ground attached to the premises without regard to its suitability—a practice responsible for much nuisance.

A water-tight cesspool is merely a place for the temporary deposit of sewage; a non-water-tight cesspool with the adjoining subsoil may be—at least in part—regarded as a place of disposal.

The sewage in the cesspool is not purified nor even rendered innocuous during the period of retention—a fact evidenced by the effluvium noticeable during removal. Sedimentation of solid matters, however, occurs, and anaerobic fermentation (i.e. decomposition of organic matter by bacteria without air) ensues and brings about breaking-down and liquefaction of a large proportion of the organic solids, and thus makes them much more readily oxidizable. This bacterial action is synonymous with that taking place in a 'septic' tank; but owing to the retention of the sewage in the cesspool for too long a period over-septicization often follows, with the evolution of sufficient sulphuretted hydrogen to cause nuisance.

The organic matters in liquefied sewage percolating from a newly-constructed non-water-tight cesspool, or one provided with an overflow, into adjoining porous, clean, and suitable soil not too far below the surface[1] are oxidized by aerobic action (i.e. decomposed by bacteria in the presence of air) and converted into innocuous substances; but if the percolage is continued without change of soil the latter soon becomes sodden and sewage-sick—a condition terminating the oxidizing process.

Thus it may be judged that, owing to the necessary limitation of size, water-tight cesspools fail to afford the proper sewage storage accommodation for premises having many occupants unless adequate arrangements are made for frequent removal of the sewage. If not water-tight they produce unfavourable soil conditions, seriously affect the atmospheric cloak, and possibly endanger the water-supply if obtained from shallow wells. They should only be accepted as temporary expedients for storing sewage in the absence of a system of sewerage or a definite

[1] See p. 401.

and effectual method of purification, and no justification exists on sanitary grounds for their inception or continuance if any one of the methods of purification hereafter mentioned is applicable.

Discharge of Sewage into Streams

The Rivers Pollution Prevention Acts, 1876–93, prohibit the placing of solid matters in any stream so as to interfere with its flow or pollute its waters. The 1876 Act lays it down that a person 'who causes to fall or flow or knowingly permits to fall or flow or to be carried into any stream, any solid or liquid sewage matter' commits an offence against the Act; with a proviso that a person discharging sewage through a channel in use or in course of construction at the passing of the Act shall not be deemed to have committed an offence if he can show that he is using the best practicable and available means (in the case of manufacturing and mining pollutions, 'reasonably' available means) for rendering the sewage harmless.

A 'stream' includes the sea to such extent, and tidal waters to such a point, as the Minister of Health may, after local inquiry and on sanitary grounds, determine.[1] With this saving it includes rivers, streams, canals, lakes, and water-courses. Thus sewage may be discharged in a crude state direct into the sea or a tidal river unless expressly forbidden; but on no account into non-tidal rivers, &c., without purification.

In addition to these preventive powers certain Conservancy Boards, Water and Riparian Authorities are enabled by private Acts to protect against pollution of streams from which water-supplies are obtained.

Discharge of Crude Sewage into the Sea

Crude sewage can safely be discharged if the outfall is below low-water mark and in a position where the sewage is permanently carried out to sea at all states of the tide.

[1] See also The Salmon and Freshwater Fisheries Act, 1923.

Where the outfall is above low-water mark putrefying sewage is likely to be deposited on the beach or foreshore —sometimes amongst seaweed by which solid particles are retained—and failure to select a position where the currential movement carries the sewage directly out to sea may eventuate in surface conveyance (sewage being lighter than sea-water) alongshore through bathing-places, with liability of the deposition of solid matters on the beach. In determining the position of the outfall close attention should therefore be given to the coastal currents and also to the direction of prevailing and other winds having a tendency to drive floating matters inshore.

In many instances discharge is restricted to the ebb or other period, necessitating an adequate storage reservoir for the sewage during retention—normally not less than six hours' storage—unless the content of the drain is sufficient for the purpose. The drain should be fitted with a reflux valve, as in Fig. 123, p. 234, to prevent the entry of sea-water and the backing-up of the sewage. The pipes should be of heavy cast-iron with caulked joints; flange joints are liable to loosening by wave action. Adequate support is essential, and if a good natural bed is absent, or if the pipe is above the beach-level, may take the form of piles fitted with cross-trees below and above the pipe. If practicable the pipe should be buried; failing this, covered with concrete—which serves as a protection, prevents scouring of the bed between high and low water, and is an aesthetic finish compared with an exposed pipe.

Discharge of Crude Sewage into a Tidal River

Sewage may be discharged into a river having a strong tide and a large volume of surface drainage water if such discharge is limited to the ebb tide only. If the tide is weak, the volume of drainage water small, or the sewage outfall far distant from the sea, sewage may be carried down on the ebb and returned on the flood to within a short distance of, or even above, the outfall, oscillated or

regurgitated from point to point, and its progress to the sea much retarded, with the probability of the deposit of decomposable solids on the banks or foreshore.

In no circumstances should discharge take place on a flood tide, as the sewage is bound to be carried up-stream, possibly several miles above the sewage outfall. For the flood period storage accommodation is indispensable. The outfall without exception ought to be not only below low-water mark but as near mid-stream as practicable, and the drain constructed of heavy cast-iron pipes with caulked joints and a reflux valve.

'Easy' *v.* 'Safe' Methods

The discharge of crude sewage into the sea or a river is an easy and cheap method of disposal. Where a quick and permanent discharge to the sea is uncertain the sewage should, as a safety measure, be treated by a sedimentation process sufficient to eliminate the solid matters. For discharges into a strong tidal river such treatment is also desirable, while for discharges to tidal rivers of small volume, shallow depth, or low velocity, or into the upper reaches distant from the estuary, adequate purification is imperative.

Discharge of Crude Sewage into a Non-tidal River, Canal, Lake, or Water-course

The discharge of crude sewage is, as stated above, definitely prohibited, and where advantage is taken of such an outlet for sewage matters purification must first be undertaken.

XXIII

SEWAGE PURIFICATION AND DISPOSAL: LAND, PRECIPITATION, AND BACTERIAL PROCESSES (1)

Purification of Sewage

PURIFICATION may briefly be described as a process of clarification followed by the oxidation of all organic matters, the operative agents being mechanical, physical, chemical, and biological. The principles of purification are identical whether applied to the sewage of a town or a single dwelling, any difference being merely one of extent; always provided that domestic sewage is distinguished from commercial sewage needing a specialized form of treatment.

Methods

To quote the Report of the Royal Commission on Sewage Disposal:[1] 'Methods of sewage treatment may be classified according to the extent to which they carry the process of purification, viz. incomplete systems as (1) simple settlement or septic tank treatment, and (2) settlement with the aid of chemical precipitation, the main effect of which is the reduction of the solids suspended in the sewage, with but little effect on the dissolved impurities; and (3) complete systems, including biological treatment of the liquor in artificially constructed filters or on land.'

The various modern methods may be listed as: (*a*) *land processes:* (i) surface irrigation, (ii) land filtration; (*b*) *precipitation processes:* (i) mechanical, (ii) chemical; (*c*) *bacterial processes:* (i) septic tank treatment, (ii) aeration treatment. A land process may be complete in itself or combined with a preliminary treatment. The other processes are commonly associated with a preliminary or final treatment, or both.

[1] Eighth Report, 1912.

Preliminary Treatment of Crude Sewage

Whatever the method of *purification*, much may be said in favour of submitting crude sewage to a preliminary treatment with the object of removing all or part of the coarser suspended solids and thereby preventing conveyance to sedimentation tanks, or to soil, percolating, or other types of filter, and their deposit on exposed surfaces with possible nuisance. coupled with serious clogging of the purification medium. Preliminary treatment may merely take the form of straining the grosser solids, or an incomplete purification by subsidence or settlement, chemical precipitation, or bacterial action in septic or semi-septic tanks.

Crude sewage can be directly discharged on porous, sandy, or gravelly soil, sometimes to the benefit of the soil by providing humus; but this is a practice that should be limited to cases where the volume is not large. With raw-sewage discharges the carriers accumulate much solid matter and in effect act as settling tanks.

If the soil utilizable for purification is of heavy clay or other impervious substance preliminary treatment (screening and/or sedimentation) should be given; also in all instances, irrespective of the means of purification, where disintegration of the sewage has not taken place. Sewage conveyed to a domestic installation is seldom broken down to the extent of permitting direct application to filter-beds.

Elimination of Grease

To prevent coagulation of grease in the conveying pipes and the clogging of land and filter surfaces, as large a proportion as is practicable should be eliminated from the sewage by the use of retaining traps of the type illustrated by Fig. 113, p. 228.

Screening

With small domestic installations, where attention requisite to maintain the screen in working order cannot

be given, screening should, if possible, be avoided. If a sedimentation tank is employed there is no difficulty in omitting the screen, but if the sewage is discharged direct to the land or a percolating filter, a small detritus tank or

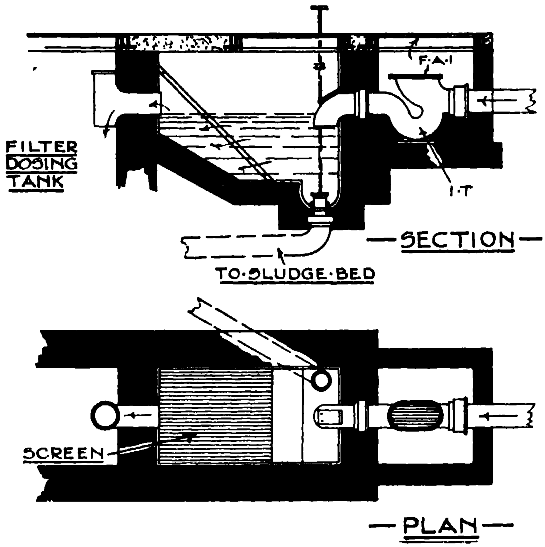


FIG. 262. Screening chamber with bar screen.

chamber with screen, as in Fig. 262, is an indispensable adjunct. The solids thus strained off can be run into a sludge-bed or buried as night-soil (Chapter XXII, p. 400).

Settling or Sedimentation Tanks

Settling tanks are in many forms, but they all function either (*a*) continuously, or (*b*) intermittently, the latter worked with 'rest' or quiescent periods. With large installations, the clear top liquor is usually drawn off by a floating-arm outflow pipe. The continuous type is the least expensive, but the intermittent-flow type secures better sedimentation. Generally, the efficiency of all such tanks varies almost inversely with the rate of flow or period of retention, the slower the flow or the longer the retention, the more effectual the sedimentation of the solids.

The process of sedimentation may be simply mechanical or may be expedited and improved by the addition of substances which will throw down the suspended solid matters and thus bring about better clarification of the sewage.

'Mechanical' Settling Tanks

'Continuous-flow' tanks act as such where the sewage is received day and night without intermission, the rapidity of the flow alone varying; but with small schemes dealing only with 'soil' sewage the operation is mostly limited to a working day of fifteen to eighteen hours, there being practically no night flow, thus giving a rest period during which the contents of the tank are undisturbed. If a dosing siphon is installed intermittency also obtains during the working hours, the sewage being retained in the tank for long or short periods as governed by the action of the siphon. In many such cases the description 'continuous flow' is somewhat of a misnomer.

'Intermittent-flow' tanks are generally made up of two or more units, one or more full of sewage (in which it is retained for a set period, commonly two or three hours) and one in course of filling. Unless fitted with automatic control valves the tanks call for constant personal attention in the working. For 'domestic' installations the intermittent method is less desirable than the continuous unless the intermittency is automatic, e.g. as secured by the use of a dosing siphon.

Chemical Precipitation Tanks

These are worked on the principle of the deposition of the organic matters in suspension and certain of those in solution by the addition of a chemical reagent to the sewage, either in the inlet channel or in the tank itself. Of the various precipitants in common use, lime (in the form of milk of lime), ferrous sulphate, and alumino-ferric are now mostly favoured, applied either separately or conjunctively. The clarification is better than that

obtaining with natural settlement and consequently there is a larger amount of sludge. The latter is also augmented by the solid matters in the reagent. Lime-precipitated sludge is 'much more prone to putrefactive decomposition than septic-tank sludge'.[1]

The necessity of giving regular attention to the application of the reagent (particularly when a 'mixer' is required) and the amount of resulting sludge renders the method less convenient for a 'domestic' installation than either a settling or septic tank; but as deodorization of the sewage can be effected the method is distinctly useful for trade refuse. Chemical precipitation rarely causes nuisance except during 'sludging', an operation provocative of offence in all tank processes.

Septic Tanks

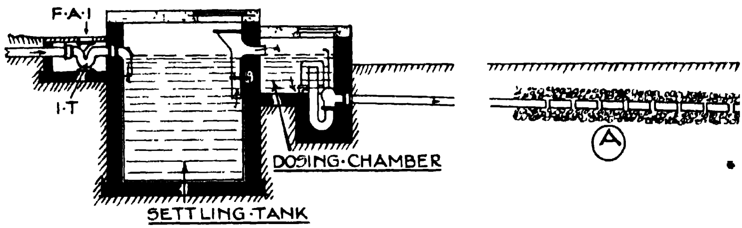
In these (Figs. 263 and 264), clarification of the sewage is secured by mechanical settlement and the partial decomposition of organic solids by anaerobic action. At one time it was claimed that the bacterial action digested and thus disposed of all the organic solids and destroyed all pathogenic organisms. Experience has dispelled this claim, but nevertheless a reduction of from 20 to 30 per cent. in the settled organic solids is effected.[2] The liquor from a septic tank is usually strong smelling and not infrequently offensive. If sewage is retained too long in a septic tank over septicization takes place with the production of much sulphuretted hydrogen, causing offence on discharge and militating against the subsequent treatment of the liquor on filters. The maximum period of retention should not exceed twenty-four hours. Open and closed septic tanks show no difference in working results, but nuisance is sometimes noticed from the open type.

1 *Second Report of the Royal Commission on Sewage Disposal*, 1902, p. 11.

2 Observations made for the Royal Commission on Sewage Disposal at Exeter and Ilford disclosed a respective digestion of 25 and 30 per cent.

Non-septic and semi-septic tanks

In these the putrefying process is carried only so far and no farther than is necessary to secure the breaking



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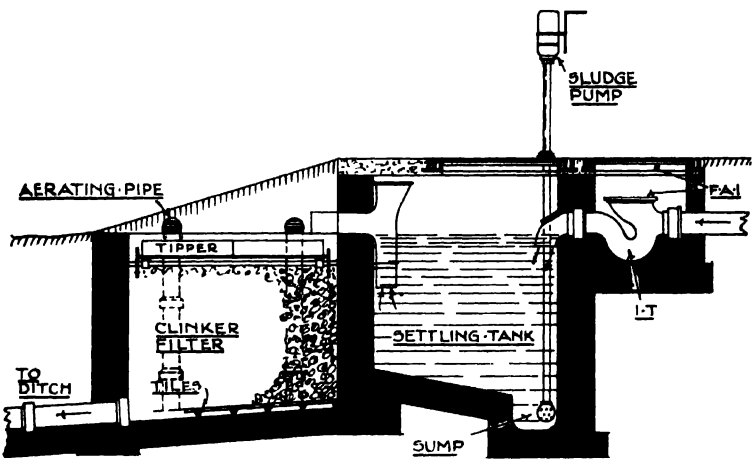

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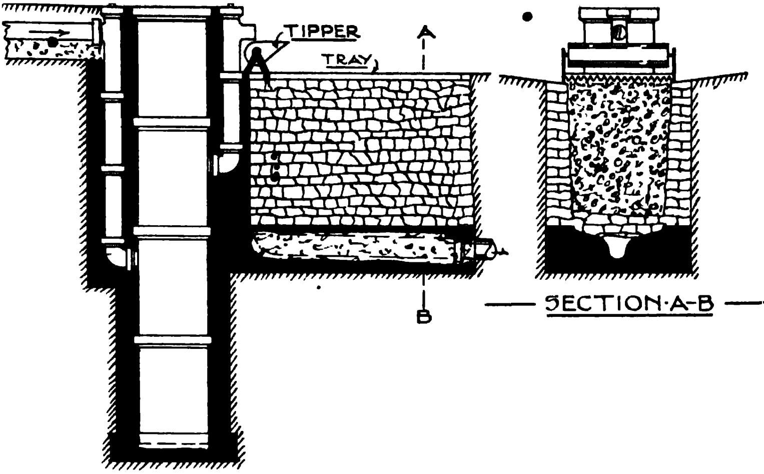
FIG. 263. Simple septic or settling tank with dosing chamber and siphon for discharging effluent through sub-irrigation drain into porous subsoil.

FIG. 264. Septic or settling tank with hand sludge-pump, tipper, percolating filter, and effluent drain to outfall.

down of the crude solids, a deep but small-diameter tank being used (Figs 265, 266, and 267) with inlet and outlet pipes carried down towards the bottom so as to change the lowermost liquor and thus limit its exposure to septicization. The process is a modification of the septic tank, for as the period of sewage retention is determined by the



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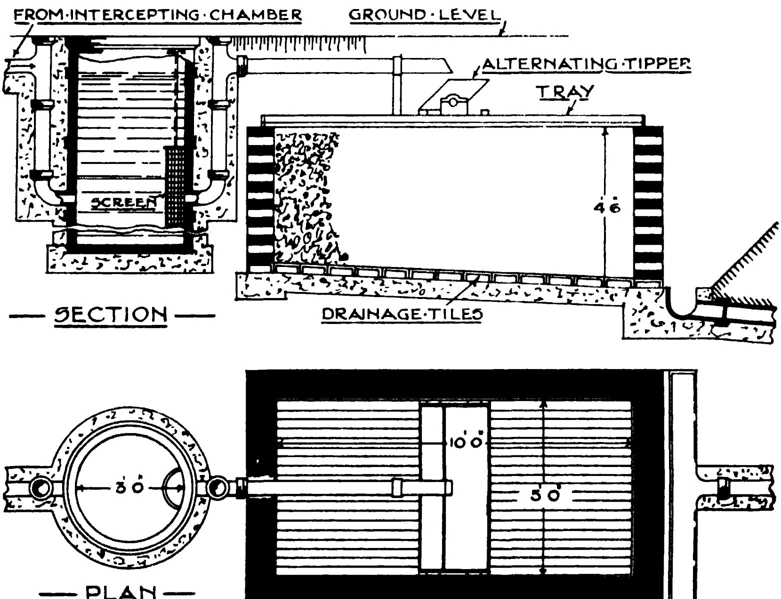

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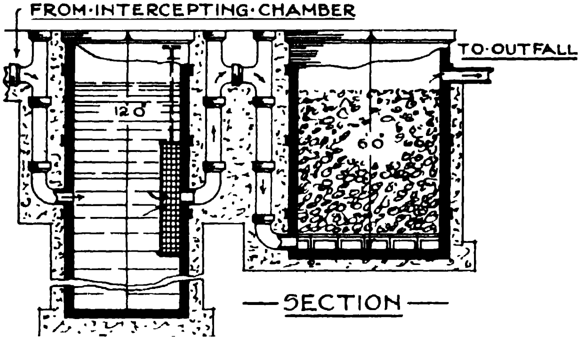
FIG. 265. Small domestic 'non-septic' tank with tipper, tray, and percolating filter.

FIG. 266. Adamsez 'Helios' non-septic tank (6–12 ft. in depth), tipper and percolating filter with aerating openings in walls.

flow, it follows that during periods in every day (and definitely at night) the contents of the tank will remain unchanged and are consequently subject to anaerobic action.



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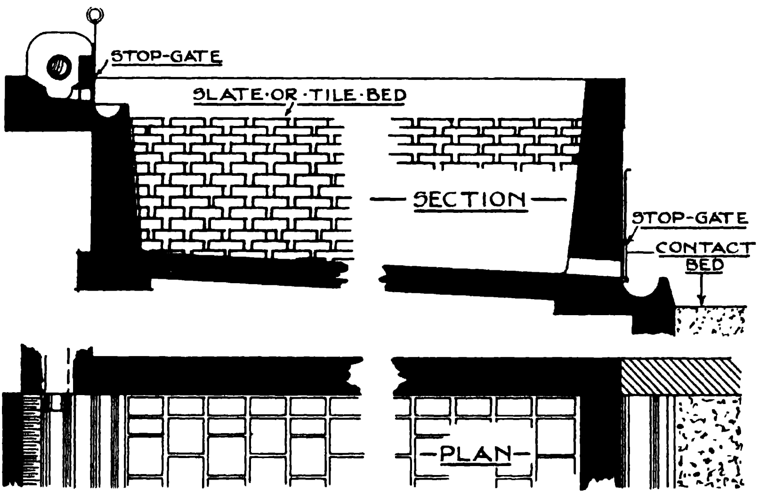

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FIG. 267. Adamsez 'Cleanos' non-septic tank with upward filter.
FIG. 268. Dibdin's biological contact bed.

Dibdin's Biological Beds

These beds are arranged as water-tight tanks filled to a depth of from 3 to 4 ft. with layers of slates lapped horizontally and separated by slate or ware blocks so as to

leave a space of about 2 in. between the layers as in Fig. 268. The arrangement is designed to provide the largest possible area for the deposition of a thin layer of 'live earth' from the fresh sewage and its use as a culture of aerobic organisms (as distinct from anaerobic organisms in a septic tank), larvae, etc., whose purpose is to digest the organic solids sedimented on the surface of the slates. The bed thus formed really constitutes a large-pore contact bed.

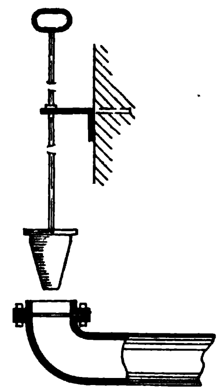


FIG. 269. Hardwood sludge-plug (Adams-Hydraulics, Ltd.).

The crude sewage is passed through a grit chamber to the bed in which it is allowed to remain for a period determined by its strength, strong sewage being permitted generally to rest in the bed for from 2 to 3 hours, and weak sewage with very little matter in suspension run off almost at once. For the best results one filling a day is suggested, thus providing for thorough aeration; and for the process it is claimed that the amount of sludge is considerably reduced, is inoffensive, and can be dried in a humus bed without causing nuisance. The operation of the bed needs daily attention and therefore the process is only suitable for installations where proper oversight can be given.

'Other' Sedimentation Tanks

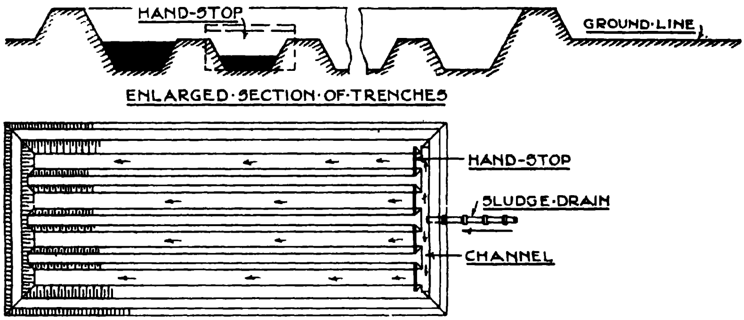
Amongst other sedimentation processes may be mentioned the Travis Hydrolytic, the Fieldhouse, the Dortmund, and the Digestion tank, the adoption of which is mainly restricted to large installations.

Sludge

The solids deposited in settling tanks are in the form of sludge, a foul-smelling mixture[1] of varied composition

[1] From this description sludge from the slate beds described above, and activated sludge may be exempted.

containing from 80 to 96 per cent. of moisture. In small installations the sludge can be removed by hand, or pumped out from the tank. Large installations require tank outlets fitted with plugs (Fig. 269) or valves so that the sludge can be run direct by a carrier, or into a well



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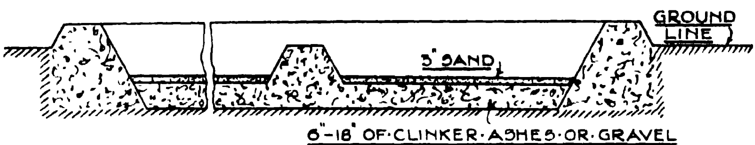

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FIG. 270. Shallow trenches for drying and burying sludge.
FIG. 271. Section through sludge lagoon or drying bed formed with sand, clinkers, &c.

from whence it can be raised by a pump, air-lift, or ejector to a trench, lagoon, or sludge-bed.

Sludge disposal is the bugbear of all sedimentation processes, and therefore if the irrigation or filtration process is capable of dealing with the solids without chokage or nuisance, sedimentation should be reduced to the minimum. If a sludge-bed is provided, an open, sunny position away from occupied buildings ought to be selected. For a small installation a good method of disposal in reasonably porous soil is deposition in short, shallow trenches about 18 to 30 in. wide and 12 to 18 in. deep, as in Fig. 270. Where the soil is non-porous, a lagoon or bed provided with drainage as in Fig. 271 is

suggested. To prevent effluvium when exposed for draining, the surface of the sludge can be dusted over with soot or bleaching powder. The sludge should be covered with the dug-out soil as soon as it is sufficiently solidified by drainage. If properly worked this method facilitates the conversion of the sludge into an inodorous humus (as described for night-soil on p. 398) and permits re-use of the site.

Capacity of Preliminary-treatment Tanks

The capacity of the tanks is largely controlled by the character of the purification treatment to which the sewage is to be subjected. If, for instance, land treatment is in view, impervious soils require tanks of the maximum, and loose sands and gravel the minimum, capacity for sedimentation. Therefore the processes of sedimentation and purification must be jointly considered.

For tanks used on the intermittent-flow system the capacity may be based on 8 per cent. of the D.W.F. in one hour, with a period of two hours for effectual sedimentation, i.e. a tank of three units each holding 8 per cent., with a fourth unit to allow for cleaning out; or a total tank accommodation equal to 32 per cent. of the D.W.F. For continuous-flow tanks one-half of this capacity (i.e. two tanks each holding 8 per cent. of the D.W.F.) will be sufficient; and for septic tanks two tanks each of a capacity of 12 hours' flow. This is for sewage only; if surface- or storm-water enters the system the capacity of the tanks should be enlarged so as to take not less than three times the D.W.F.

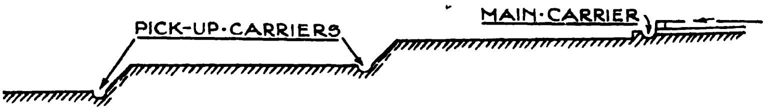
The Minister of Health's requirements[1] in respect to the capacity and number of tanks for different systems of preliminary treatment are (public schemes):

Detritus tanks. Two or more, each of $\frac{1}{100}$ of the D.W.F.
Septic tanks. Two or more, each of 12 hours' flow.
Continuous settlement. Two or more, each of $7\frac{1}{2}$ hours' flow.

[1] *The Ministry of Health Requirements*, S. H. Adams.

Continuous precipitation. Two or more, each of 4 hours' flow.
Quiescent precipitation. Eight or more, each of 2 hours' flow.
Humus tanks. Two or more, each of 1 hour's flow.

These tanks provide for the reception of storm-water up to three times the D.W.F. For storm-water in excess of this two additional tanks having a combined capacity of one-fourth the D.W.F. are needed.



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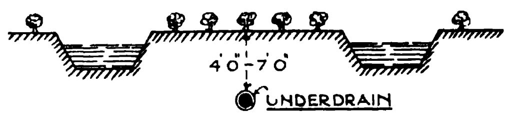


273

FIG. 272. Terraced surface for broad or surface irrigation.

FIG. 273. Ridge-and-furrow method of surface irrigation combined with under-drains.

For works provided in connexion with elementary schools the Minister of Health stipulates:[1] 'The capacity of tanks which overflow on to a filter bed or irrigation area need not exceed from one to two days' volume of sewage, which may generally be assumed at $2\frac{1}{2}$ gallons per head, of the accommodation provided (including teachers) at the school if w.c.'s are used, or at 1 gallon per head where only urine and slop water have to be dealt with.'

Methods of Purification

Adequate sedimentation in tanks removes from the liquid most of the suspended matters, and anaerobic action breaks down and liquefies much of the suspended organic matter. The joint processes produce a liquid in a condition more readily favouring oxidation, but do not, in themselves, effect purification of the sewage: hence further treatment is essential. Of accepted purification methods, attention may be drawn to the following.

[1] See footnote 1 on p. 147.

Surface or 'Broad' Irrigation

This consists of flooding, by means of carriers or grips, the surface of embanked agricultural land having a fall of about 1 in 300 to a main surface-drain or outlet, with 3 to 6 in. of sewage, or discharging it into furrows from which it percolates into ridges or bays, so that the solid

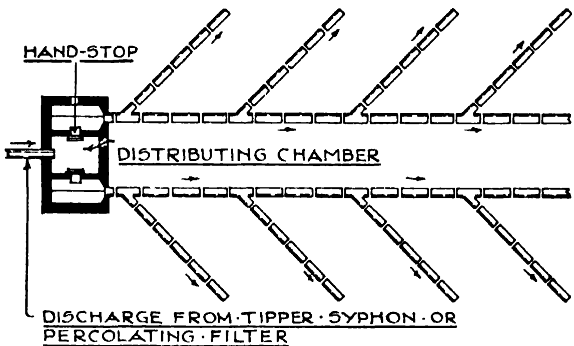


FIG. 274. Plan of subsoil drains.

matters are deposited and retained in the surface soil and the liquid absorbed into the soil mass. Fig. 272 shows surface laid out in terraces, and Fig. 273 the ridge-and-furrow method. Purification is effected in the surface soil by the oxidation of the putrescible organic matters. Cultivation of the soil is essential to the process, as dependence is placed on the growing vegetation to use much of the organic matter, evaporate the liquid, and so prevent sewage-sickness of the soil.

It is somewhat difficult to differentiate between surface irrigation and downward filtration, for it is obvious that a considerable percentage of the liquid discharged on the surface pursues a downward course through the soil. More often than not the process is irrigation combined with filtration, the main difference being the absence of under-draining where surface irrigation is depended upon.

Land or 'Intermittent Downward' Filtration

This process is one of downward percolation through the soil to a network of subsoil drains. The sewage may be allowed to flow over a level or nearly-level surface, or conducted into the soil by open-jointed pipes laid about 1 ft. below the surface (Fig. 274 and Fig. 263 (A)). Purification is by nitrification, and its effectiveness depends mainly upon the depth and character of the soil through which the sewage percolates. For treatment a smaller area is required than with surface irrigation. The surface is best cultivated, as by so doing soil aeration is maintained, but the absorption of sewage by vegetation is a secondary matter compared with the purification effected during filtration.

Surface irrigation and filtration are often combined, and as the details of the methods have much in common they may be mentioned together. Many of the following notes are framed on the conclusions and suggestions of the Royal Commission on Sewage Disposal.[1]

Soils

The purification values of soils show enormous differences. Any kind of soil can be used if the volume of sewage discharged thereon or therein is proportionate to its purifying capacity, and it would seem that with proper management a plot of land will purify sewage for an indefinite period. For surface irrigation light loamy soil overlying gravel or sand is the most, and chalk, clay, peat, and waterlogged soils are the least, suitable. In order of priority for filtration, light loamy soil overlying a porous subsoil is excellent; a sandy soil and subsoil and a partially peaty soil overlying gravelly sand are good; but peat pure and simple is not well adapted to this purpose.

Carriers

Open are preferable to piped carriers, and the mains

[1] Fourth Report, 1904, vol. iv, Parts i and iv.

should be in the form of channels lined with earthenware, stoneware, brick, slate, stone, or cement (Fig. 275). Earth carriers encourage the growth of vegetation and the sides are subject to damage by rats, moles, &c.

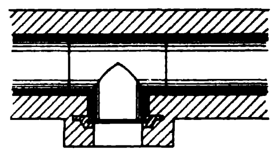


FIG. 275. Plan of semi-circular main carrier and branch feed to trench, &c., fitted with hand-stop.

Surface irrigation requires a greater number of subsidiary carriers (commonly in the form of furrows) than filtration, and pervious soils than impervious. The cultivated plots should be kept as small as workable as this allows for better distribution of the sewage.

Under-drains

With filtration land, if the surface and subsoil are porous, only sufficient under-drains need be laid to secure removal of the percolated liquid. Waterlogging of the soil is inimical to effectual purification with both irrigation and filtration processes. Deep ditches with a good outfall lower the subsoil-water level. Normally the drains for filtration should be laid from 5 to 7 ft. in depth, and where the level of the water is within 4 ft. of the surface complete under-drainage should be effected so as to increase the soil depth available for purification. It must not be lost sight of that all under-drains assist in aerating the soil. Where necessary to remedy or prevent waterlogging, subsoil drains should be provided to irrigated land.

Except where the effluent can be raised at the outfall and re-treated on the surface, under-drainage of dense clay should not be done as it increases the tendency of the soil to fissure in dry weather—thus permitting the liquid sewage to pass into the drains without proper treatment. Turfing clay soil mitigates the tendency to crack.

The distance apart of the under-drains must depend upon the nature of the soil and subsoil and the volume of

sewage treated. A porous soil overlying loose gravel drains rapidly and hence ample drainage facilities are needed, whereas percolation is very slow through fine soil over a sand subsoil.

Under-drains can be of unjointed agricultural pipes, or of stoneware—half-socketed, or socketed with open joints. The first mentioned, being porous, are best for subsidiary drains, but the main or master-drains should be of socketed stoneware. Laying at right angles or diagonally to slope of ground is recommended.

Area of Land needed

This depends upon the preliminary treatment given to, and the strength of, the sewage, the nature or purification value of the soil, and the required standard of effluent. These are such variable factors that it is impossible to lay down any definite rule as to the exact area required for purification. Actual experience of filtration works and experimental installations shows that the purification value of a cubic yard of soil varies from less than 1 to 10 gallons of sewage per 24 hours.[1]

The report of the Royal Commission on Sewage Disposal[1] put the approximate purification value of suitable soil for filtering mechanically-settled sewage of medium strength at 30,000 to 60,000 gallons per acre per 24 hours at a given time (750 to 1,500 persons per acre), and 10,000 to 20,000 gallons calculated on the total irrigable area (250 to 500 persons per acre); and for soils not well suited for surface irrigation or combined surface irrigation and filtration at 5,000 to 10,000 gallons per acre (125 to 250 persons per acre), and 1,000 to 2,000 gallons calculated on the total irrigable area (25 to 50 persons per acre).

The rules of the Local Government Board provided that for public schemes: 'Where an area of land is provided for

[1] Vol. iv, Part i.

the final purification of the sewage or sewage effluent . . . it should be in the proportion of not less than one acre to every 150 persons of the population served by the scheme if simple broad irrigation (without preliminary treatment) is to be adopted, and in the proportion of not less than one acre to 1,000 persons or 30,000 gallons of sewage per diem if there is to be preliminary treatment of the sewage in tanks and filters or contact beds.' It is generally accepted 'that good land with suitable soil and subsoil can purify at a given time about 30,000 gallons of well-settled sewage per acre per 24 hours by filtration';[1] i.e. about 6·2 gallons per square yard of surface.

The whole area cannot, of course, be worked at one time, and working and resting areas may respectively be put at one-third and two-thirds. This being so, the above-mentioned volume of sewage per acre must be reduced by two-thirds or the total filtration or irrigable area correspondingly increased to take the desired volume.

With a sewage yield of 40 gallons per head per day from a community of 250 persons the volume of sewage is 10,000 gallons. Filtration through good soil would require a total irrigable area, on the basis suggested by the Royal Commission, of approximately:

$$\frac{10000}{6\cdot 2} \times 3 = 1 \text{ acre.}$$

For land not well suited for filtration the total irrigable area for the volume here stated should, on the above-mentioned basis, be increased to 5 acres. Similarly the area needed for surface irrigation can only be determined approximately. Kershaw[2] puts 'the ratio of area necessary for surface irrigation to that requisite for filtration' as 2–4 to 1. The total irrigable land should be sufficient in area to permit of but one-fifth being under sewage at a time. Thus, assuming an area of twice that needed for

[1] *Sewage Purification and Disposal*, Kershaw, pp. 172–3.

[2] Ibid. Newman in *Bacteriology and the Public Health*, p. 161, suggests 1 acre to every 100 of the population.

filtration, and the sewaging of one-fifth at a time, for 10,000 gallons the requisite area may be put at

$$\frac{10000}{6 \cdot 2} \times 2 \times 5 = 3 \cdot 4 \text{ acres}$$

as compared with one acre for filtration.

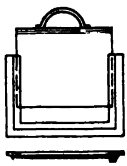


FIG. 276. Hand-stop and frame.

If the land is not well suited for purification purposes the total irrigable area should be correspondingly increased as suggested for filtration soil.

For disposal of sewage from an elementary school it is laid down [1] that:

'Land for irrigation should have an adequate area and suitable soil, and should be at a sufficient distance from any inhabited building or sources of water-supply, so as not to create a nuisance or to pollute the water.'

Application of Sewage to Land

The sewage should be applied to the land intermittently, the timing being arranged so as to ensure sufficient periods for percolation and the maintenance of the soil in a 'drained' condition permitting thorough aeration prior to receiving a further sewage content. With both surface irrigation and filtration it is usual to sectionize the site by carriers or feed-channels fitted with hand- or pen-stocks (Fig. 276), allowing diversion of the sewage as found necessary. A very general rule is a working period of eight hours and a resting period of sixteen hours.

Contact Beds

Purification can be effected in contact beds consisting of non-disintegrating materials having, *in situ*, ample voids or interspaces. The process presents three phases known as (1) single, (2) double, and (3) triple contact, in a series as primary, secondary, and tertiary beds (Fig. 277). The extent of adoption of the process depends upon the nature of the sewage and the degree of purification required.

[1] See footnote 1 on p. 147.

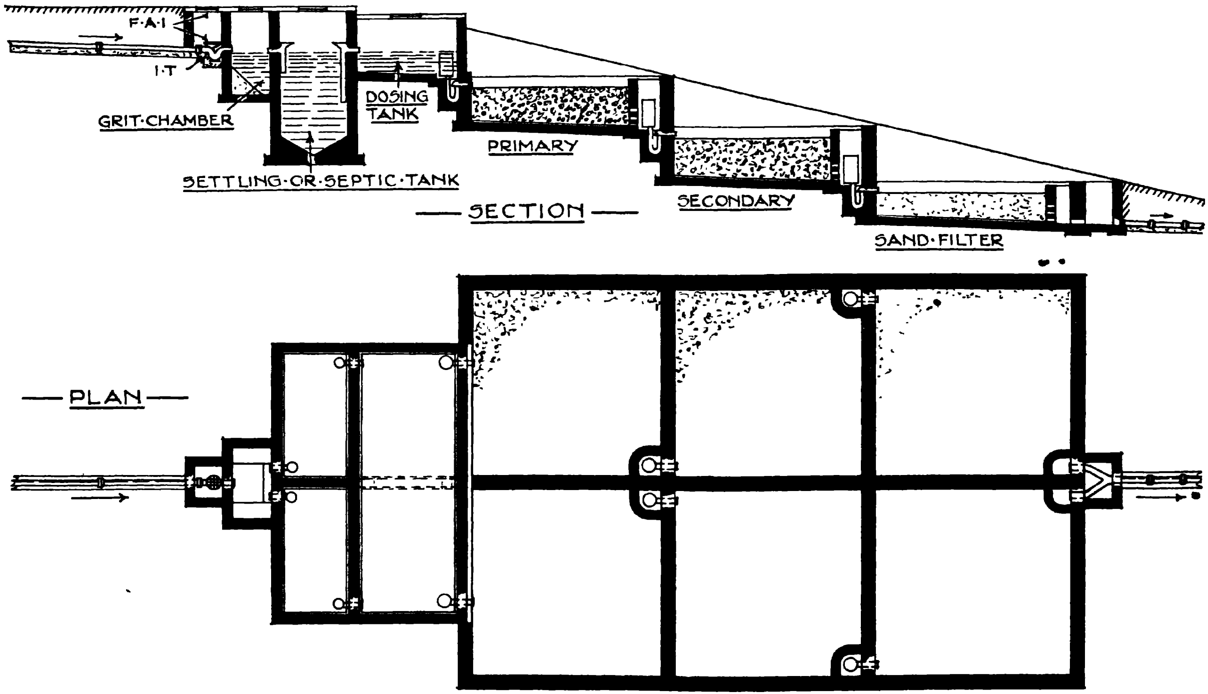


FIG. 277. Primary and secondary contact beds, sand filter, settling and dosing tanks in duplicate, with grit chamber and automatic siphons.

Crude sewage which has been subjected merely to screening can, if disintegrated, be discharged on to a primary bed formed of a coarse-grade material with large pores or interspaces, but clogging and silting up of the bed is likely, with a serious reduction of its working capacity. Where this practice is adopted a secondary bed is required for further treatment. Single contact is sometimes followed, but as a general rule double contact is necessary to ensure a reasonable standard of purification. If the sewage is strong triple contact is advisable, and where the effluent is discharged into a stream from which drinking-water supplies are obtained a final treatment on land may be desirable.

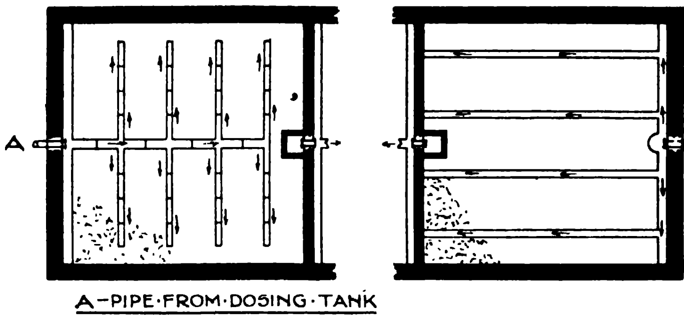
The purification process is complex, the most important agents probably being aerobic bacteria, but, as expressed in the Fifth Report of the Royal Commission on Sewage Disposal, 'little is known as to the manner in which the organic substances of sewage are broken down during the first stage of fermentation into carbon dioxide, ammonia, &c. The purifying agents seem to be not only bacteria, but also worms, larvae, and insects, and we can offer no opinion as to the respective amount of work done by each set of agents'.

The working operation is to charge the primary bed with liquor from a settling or septic tank to within a few inches of the surface, leave in contact for a period determinable by the character of the liquor, and then run out into a channel leading to a filter, on to land for final treatment, or direct to outfall if a low-grade effluent is acceptable. If double contact is adopted the liquor from the primary bed is passed through the secondary bed, and with triple contact through the tertiary bed, before discharge on to filter or land or to effluent outfall.

Beds that have been in operation for some time give better purification results than those newly filled owing to the development of suitable bacteria and other living organisms.

Where the flow of liquor is irregular a dosing tank and siphon can be employed advantageously.

Upward filling is sometimes resorted to but is not recommended, as suspended matter is deposited on the



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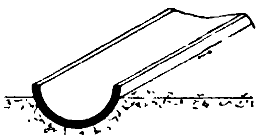

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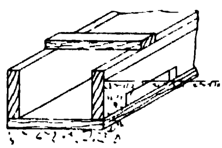

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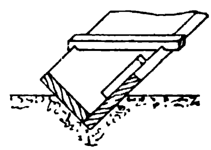

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FIG. 278. Alternative arrangement of distribution channels for contact beds. FIG. 279. Half-round stoneware channel. FIG. 280. Rectangular wood trough or channel. FIG. 281. V-shaped wood trough or channel.

floor, in the drains, and in the lower strata of the contact material, to which access for removal is difficult.

Construction of Beds

These are mostly constructed as water-tight tanks in brick, stone, or concrete, deep enough to hold about 4 ft. of contact material, and provided with inlets and outlets for sewage. The contact material should be hard and durable. Clinker, coke, broken brick and stone, gravel, and many other similar substances are used; hard, well-burnt furnace clinker is as satisfactory as any. The material is graded, coarse, medium, and fine being selected respectively for primary, secondary, and tertiary beds.

The finer the material the better the purification, but the less the volumetric efficiency. Too fine a material has a tendency to choke, and aeration is sometimes retarded by the retention of liquid in the interspaces.

In some instances the liquor is flooded on to the primary bed, but the better practice is to distribute it by

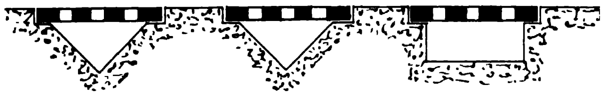


FIG. 282. Floor channels with aerating drainage tiles.

means of stoneware channels or wood troughs (Figs. 278, 279, 280, and 281). Ample under-drainage must be provided so as to thoroughly empty the bed and permit aeration. Fine beds need a larger number of drains than those filled with a coarse material.

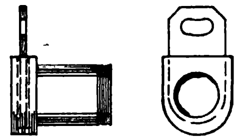
Under-drains can take the form of channels in the floor of bed covered with perforated or slotted tiles (Fig. 282) or the whole floor can be laid with tiles (Figs. 291 to 294). All troughs and channels should run quite dry. To prevent the carriage of small 'choking' particles into the under-drains a layer of coarse contact material 6 to 9 in. in thickness should be placed thereon. To secure complete aeration pipes are occasionally inserted vertically in the bed at spaced intervals, but these should not be necessary if the latter is properly constructed. Where used the pipes should stand sufficiently above the bed to prevent direct drainage of liquor and any perforations limited to the lower ends of the pipes. Carriers to or between beds should be open channels in stoneware or cement (Fig. 275) with removable covers if needed to prevent nuisance. An adequate number of retaining and emptying sluice valves, irrigation valves, or pen-stocks is required for each bed (Figs. 283, 284, and 285).

The planning of the beds should, if practicable, allow for the discharge of liquor on the surfaces by gravitation: otherwise automatic sewage lifts or ejectors can be

employed. Fig. 277 shows a series of beds served by gravitation. If a sewage lift is needed the ejector type given in Fig. 259 can be applied.

Capacity and Number of Beds

The liquid capacity of a charged bed under working conditions approximates to one-third of the bed-content when empty, or 50–60 gallons per cubic yard. The capacity is determined by the volume of sewage to be treated and the num-



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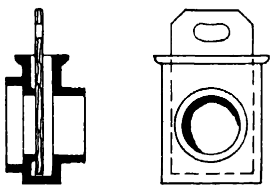

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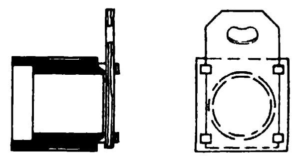

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FIG. 283. Burns's stoneware irrigation valve with wooden gate.
FIG. 284. Doulton's stoneware stop-gate with mahogany slide.
FIG. 285. Doulton's stoneware flushing-block with wood slide.

ber of fillings per diem.[1] Three fillings are quite usual. The beds should allow one hour for filling, two hours for

[1] The rules of the Local Government Board gave the following particulars for public schemes: 'In the construction of bacteria beds the . . . usual requirement is that the beds should be designed of sufficient size to deal in a day of 24 hours with a total volume equal to twice or three times the daily dry-weather flow of sewerage, according as the district is drained on the separate system or not. When the beds are to be worked on the intermittent or "contact" plan and the effluent is to receive final treatment on land one set of beds, i.e. single contact, would ordinarily be regarded as sufficient. The working capacity of the beds would be taken at one-third the empty capacity, i.e. the capacity of the tanks before the filtering material is put in; and the number of fillings per day of 24 hours must not exceed three.

'Where the filters are proposed to be worked on the continuous or percolating principle and land treatment is provided, the maximum rate of filtration allowed is 56 gallons per square yard per foot in depth of filtering material per day.

'Where the circumstances preclude land treatment the cubic contents of the filtering material in either case must be double that indicated above, i.e. two sets of contact beds or "double contact" must be provided in the case of beds worked on the intermittent plan and the rate of filtration for continuous or percolating filters must not exceed 28 gallons per square yard per foot in depth

retention of liquor, one hour for emptying, and four hours' rest. A duplicate set of primary beds, each set with a liquid capacity of one-third the D.W.F., is therefore required where rain-water is rigidly excluded, with secondary beds (and tertiary if provided) of the same capacity. If rain-water is admitted, then the provision should be equal to three times the D.W.F.

Thus for a D.W.F. of 10,000 gallons per diem, on the basis of 50 gallons per cubic yard and three fillings, the unit primary, secondary, and tertiary beds should each hold:

$$\frac{10000}{3 \times 50} = 67 \text{ cu. yds.},$$

constituting, say, a bed 25 ft. × 16 ft. with 4 ft. 6 in. of contact material. Two such units would be needed. Fig. 277 illustrates the lay-out of, and section through, beds for such an installation.

Control of Beds

The filling and emptying of beds and the change-over from one series to another can be secured by automatic appliances, but some of these are apt to get out of order and therefore require daily attention by a person conversant with the working of the purification process. Contact material needs taking out and washing or replacing by new when the liquid capacity of the bed is so far reduced as to render it ineffective.

of filtering material. With regard to the question of land treatment . . . where a sufficient area of land of a not unsuitable character could be provided at a reasonable cost it would be contrary to the present practice . . . to entertain a scheme which did not provide for the final purification of the sewage on land. In addition to provisions as above mentioned for the full treatment of sewage up to three times or twice the dry-weather flow as the case may be . . . provisions should also be made in the scheme for dealing with excess liquid beyond that volume up to at least six times the dry-weather flow.'

XXIV

SEWAGE PURIFICATION AND DISPOSAL: LAND, PRECIPITATION, AND BACTERIAL PROCESSES (2)

Percolating or Continuous Filters

IN contradistinction to contact-beds, in which tank liquid is ponded for a fixed period, percolating filters (Figs. 286 and 287) are designed for direct passage of the liquid through the filtering mass, either continuously or intermittently according to the means used for applying the liquid to the filter. Purification is mainly by aerobic action, and the degree of purification depends upon adequate aeration of the filtering material and the length of time the sewage is under the influence of the bacteria.

The continuous or intermittent working of the filter often turns upon whether the available flow of sewage can be applied effectually in a continuous stream. In the event of an inconstant or inadequate flow the liquid may, on occasion, be applied as a mere trickle and limited to a small area of the filter. This is undesirable and should give place to intermittent discharges sufficient in volume to cover the surface of the filter.

The Royal Commission on Sewage Disposal classified continuous filters according to the grade of the filtrant:[1]

(1) Filters constructed of coarse material not less than 2½ in. in diameter providing for free aeration and the passage of solids in suspension right through the mass.

(2) Filters constructed of material approximating to ½ in. in diameter providing for aeration but temporarily retarding the passage of suspended solids.

(3) Filters constructed of fine material which retain the suspended solids on the surface.

Construction of Filters

The filtrant may be contained within solid walls of

[1] Fifth Report.

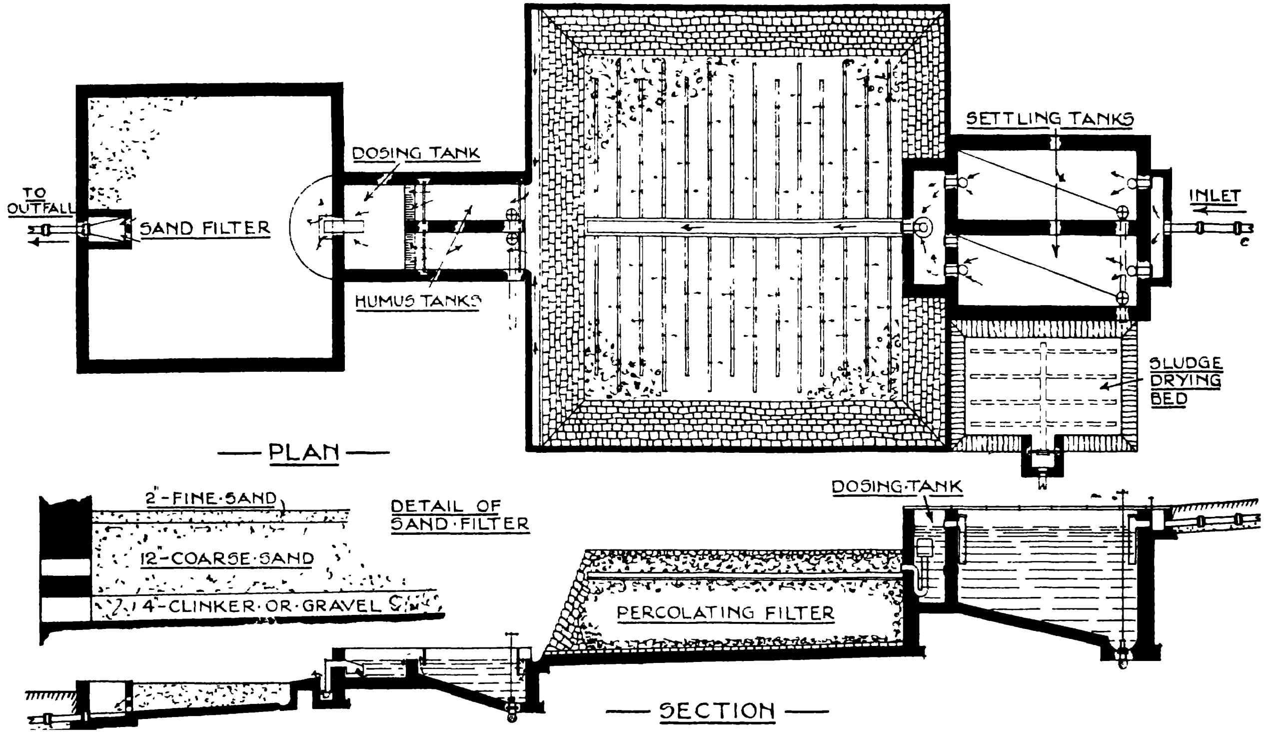


FIG. 286. Percolating and sand filters with settling and dosing tanks, automatic siphons, and sludge drying bed.

brick, stone, or concrete above or below the ground-level (Fig. 289) or built up with a carefully ramped exterior as in Figs. 288 and 290. A solid floor of smoothed concrete is necessary, laid with sufficient fall to an effluent channel of

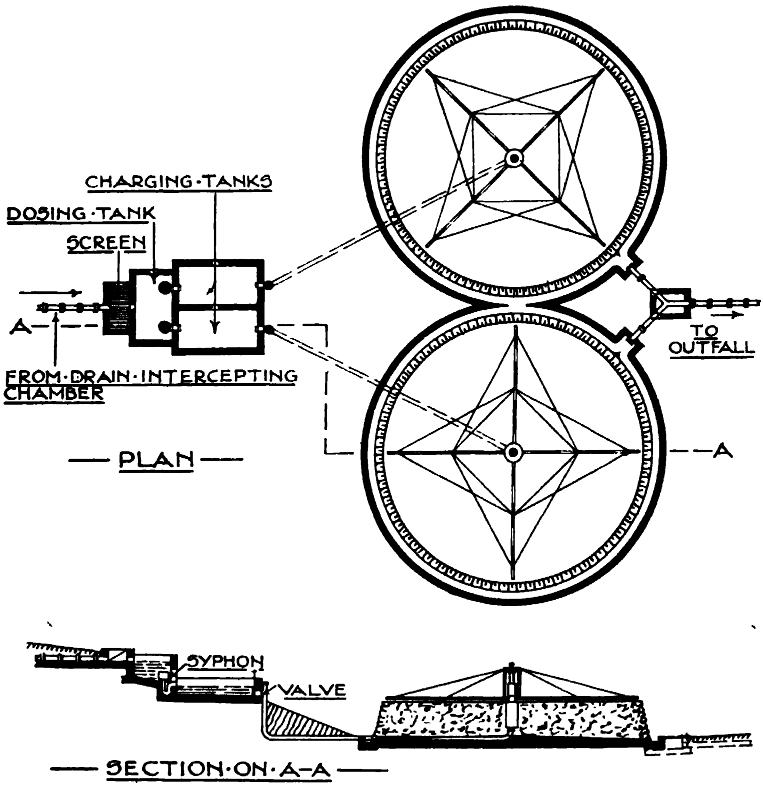


FIG. 287. Percolating filters with revolving distributors and automatic alternating siphons.

stoneware, brick, or concrete formed around the outside of the filter or the enclosing wall. A complete system of under-drains is also necessary for conveyance of the filtrate and the aeration of the filter, and is best secured by laying a false floor of special vitrified stoneware tiles (Figs. 291 to 294) carried right through to the effluent channel with a covering of from 6 to 9 in. of coarse filtering

material where the filtrant proper is of fine grade and liable to be washed into the under-drains. For the filtrant the materials suggested for contact beds (p. 433) are suit-

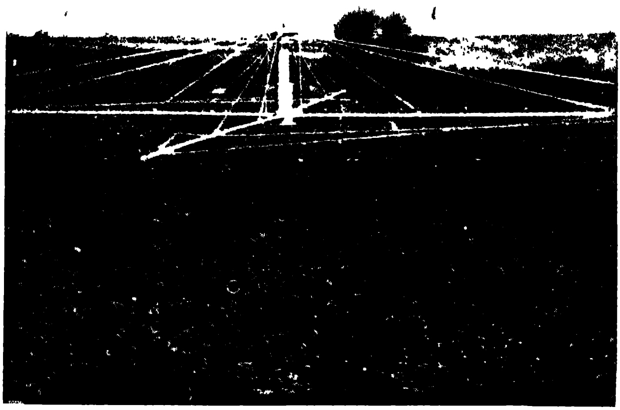


FIG. 288. View of percolating filter (Adams-Hydraulics, Ltd.).

able. An average size of $1\frac{1}{2}$ to 2 in. diameter is now commonly employed.

With newly-constructed filters the shape is usually decided upon in conjunction with the type of 'feeder' or distributor to be employed. If rotating arms are to be used the plan is necessarily circular, while for a travelling feed it must be rectangular. Small filters fitted with 'tipper' feeds are either square or oblong.

Number, Size, and Capacity of Filters

If rotary distributors are used, at least two filters are desirable so as to allow for overhauling, &c. For small installations with tippers or stationary distributors duplicates are not essential as it is practicable to put one part of the filter out of operation without entirely holding up the work of purification. The depth of the filter often turns upon the site and fall obtainable. The minimum should be 3 ft. The purification value of the filtrant is approximately identical per cubic yard, given the same rate of

treatment, and consequently it is more economical to provide a depth of 6 ft. (the one most usual) or more. The volume of liquor which can be effectually treated

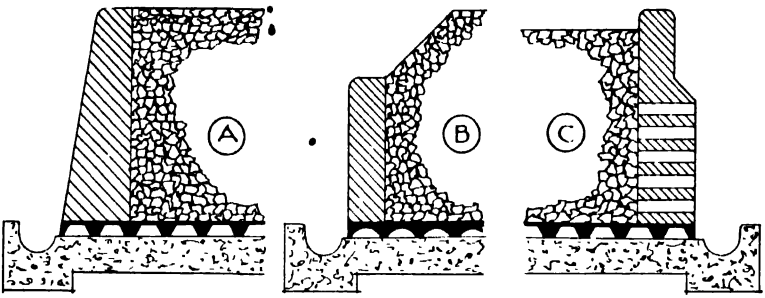


FIG. 289. Retaining walls for percolating filters. A. Solid wall full depth. B. Solid wall part depth with battering of filtering material. C. Wall with aerating openings.

depends upon its source, i.e. its preliminary treatment, and the grade of the filtrant.

The requirements of the Ministry of Health[1] for public schemes limit are:

Gallons of tank liquor allowed per cubic yard of filtrant per 24 hours, dependent upon preliminary treatment and grade of filtrant, as follows:

Sewage (strength of)	*Strong.*		*Medium.*		*Weak.*	
Filtrant (grade of)	*Coarse.*	*Fine.*	*Coarse.*	*Fine.*	*Coarse.*	*Fine.*
Effluent from:						
Detritus tanks . .	15	—	25	—	40	—
Septic tanks . .	45	—	70	—	100	—
Settlement tanks (continuous) . .	45	—	70	—	100	—
Settlement tanks (quiescent) . .	50	25	100	70	130	130
Precipitation (continuous) . .	65	50	100	80	150	175

These rates are applicable when the whole of the filter surface is in use, viz., in wet weather. If the D.W.F. is divided by the figures the cubic yards of filtrant required to deal with three times the D.W.F. can be ascertained.

[1] *The Ministry of Health Requirements*, S. H. Adams.

If storm-water is entirely excluded, then the filtrant needed will be one-third of the latter. Thus, with a flow of 10,000 gallons in 16 hours (assumed as the 'working' day) the

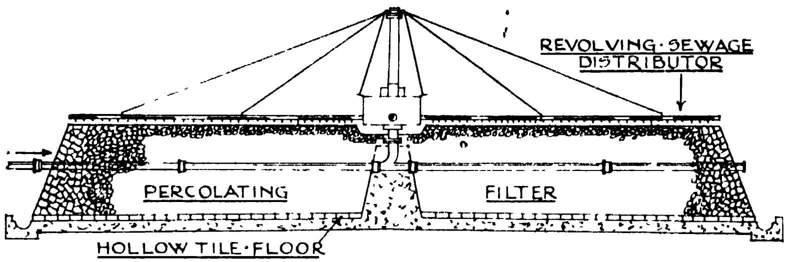
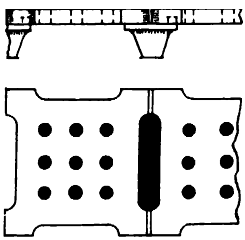


FIG. 290. Percolating filter with battered sides and revolving sewage distributor.



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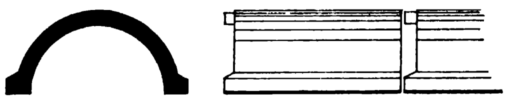

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FIG. 291. 'Newham' false floor tile.
FIG. 292. 'Mansfield' drainage tile.

rate of flow per diem is 15,000 gallons and the cubic yards of coarse filtrant needed for medium-strength liquor from a septic tank will be:

$$\frac{15000}{70 \times 3} = 72 \text{ cu. yds., or, say, } 27 \text{ ft.} \times 12 \text{ ft.} \times 6 \text{ ft.,}$$

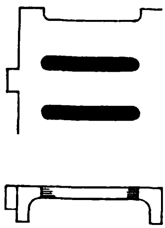
and for liquor from a quiescent settlement tank:

$$\frac{15000}{100 \times 3} = 50 \text{ cu. yds., or, say, } 22 \text{ ft. } 6 \text{ in.} \times 10 \text{ ft.} \times 6 \text{ ft.}$$

The optimum flow is sometimes put as high as 200 gallons per cu. yd. per 24 hours. For simple domestic sewage 100 gallons may be safely accepted if the effluent is passed to a sand filter and 200 gallons if given adequate filtration through land.

Where provided in connexion with the disposal of sewage from elementary schools the 'Filter beds should

be not less than 2 ft. 6 in. in depth, and the filtering medium should consist of some hard and clean material, care being taken that the liquid is evenly distributed over the surface of the filter bed by a suitable apparatus.



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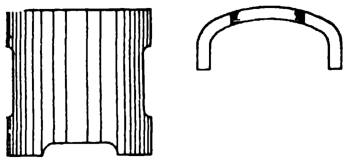

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FIG. 293. Stiff's patent aeration and drainage tile. FIG. 294. Filter bed tile (Leeds Fireclay Co., Ltd.).

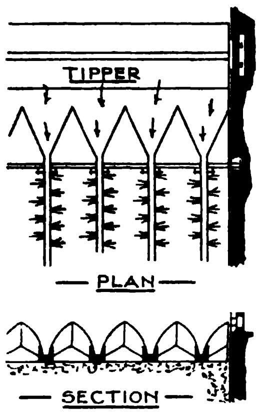
Filters should in all cases have free outlets so as to drain the whole of the filtering media. If no land treatment is provided, the area of the filter bed should be sufficient to deal with the liquid at a rate not exceeding 40 gallons per sq. yd. per day for a filter 2 ft. 6 in. deep or at a porportionally greater rate for a deeper filter. When subsequent land treatment of the effluent is adopted, a rate of filtration twice as rapid as the above may be allowed'. The filter must also be constructed so that the floor and so much of the external walls as are below ground are watertight, and the works fenced in so that they cannot be interfered with by the children.[1]

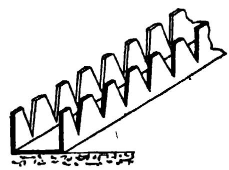
Application of Sewage to Filter

Distributing systems include a continuous flow of sewage from settling tank into a tipping trough, single- or double-acting (Figs. 264, 265, and 266), and its periodic discharge on to filter by flooding, chutes (Fig. 295), troughs (Fig. 296), or perforated galvanized-iron sheets or trays; an automatic siphon (Figs. 297 and 298) operated by the head of sewage in a 'dosing' tank filled from settling or septic tank and intermittently discharging direct or by means of channels on to filter; fixed perforated jet- or

[1] See footnote 1 on p. 147.

spray-pipes fed continuously or by a dosing siphon, the pipes sometimes being covered with a layer of clean dry clinker; a rotating spray distributor with perforated arms operated on the Barker's mill principle, the flow being either continuous or at intervals from a dosing siphon; a rotary 'Ideal' distributor fitted with an oscillating tipper





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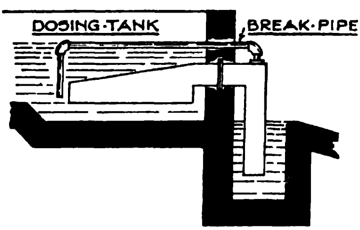

295 297

FIG. 295. Farrer's cast-iron chutes and channels for percolating filters.

FIG. 296. Tuke and Bell's cast-iron serrated-edge distributing trough for percolating filter.

FIG. 297. Adams's patent automatic low-draught flusher.

(in place of a dosing siphon) in the centre which operates the rotating mechanism and distributes the sewage through edge-serrated channel arms (Fig. 296); and travelling distributors running on rails laid each side of a rectangular filter and fed by siphon arms from continuous channels supplied with sewage.

Means of distribution should be (1) automatic, (2) without mechanical parts or appliances needing frequent attention, (3) not easily choked, and (4) should deliver the liquid sewage uniformly over the entire surface of the filter. Well-designed percolating filters will operate automatically with the minimum personal attention, and if of coarse-grade material may be without disturbance for

years. Regular examination, however, is needed to see that the distributing apparatus is in working order and the surface free from growths and other solid matters.

Contact-bed and Percolating-filter Effluents

The liquor draining from many contact beds and percolating filters carries with it an appreciable amount of suspended solids liable to putrefaction and not in a state acceptable for discharge into a watercourse. Interception of the solids is necessary and may be brought about by land treatment, or by passing the liquor into a settling or humus tank, or through a sand filter or strainer. Tanks of the Dortmund type, which are fitted with a hopper-shaped bottom into the apex of which the solids are deposited by gravitation, are serviceable. The tank should have a capacity of 2 hours' D.W.F.

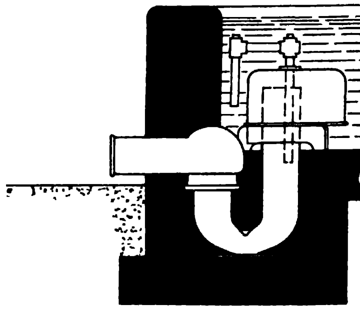

FIG. 298. 'Certus' automatic shallow-draught flushing siphon.

Shallow straining filters composed of sand or other fine-grade material, as in Fig. 286, are efficient. Kershaw suggests[1] a depth of 12 to 15 in. with under-drains, a bottom layer of 3 to 4 in. of clinker or gravel, a middle layer of 12 in. of coarse sand, and a topping of 2 in. of fine sand: for which strainer a filtration rate of 500 gallons per sq. yd. per 24 hours is given.

Nuisance from Sedimentation and Purification Processes

Possibilities of nuisance exist with all methods of sewage treatment, and it is therefore a desideratum that all works connected therewith should be as far distant from occupied buildings and places of public resort as site conditions allow. Urban and rural sanitary authorities are

[1] *Sewage Purification and Disposal*, Kershaw, p. 274.

prohibited from causing nuisance during sewage disposal,[1] and private individuals lay themselves open to prosecution if they offend in this matter.

Nuisance may arise from the preliminary treatment of sewage in sedimentation and septic tanks, from carriers between tanks and contact beds, percolating filters and land surfaces utilized for treatment, and during the disposal of sludge. Trade waste from 'tanners', fellmongers', brewers', and similar trade premises are often productive of much nuisance.

To prevent nuisance from preliminary-treatment tanks lime or other deodorizing substance is sometimes used, but this increases the amount of sludge. The covering of the tanks has in many instances effectually prevented the dissemination of foul gases, of which the principal is sulphuretted hydrogen. Carriers should be kept free from sewage, generally maintained in a clean state, and where found necessary fitted with removable covers.

The distribution of sewage (particularly that from septic tanks) on contact beds and percolating filters and the effluent from primary beds are sometimes the cause of effluvium. According to Kershaw,[2] where liquid 'is applied direct to filters either by moving distributors or stationary jets, percolating filters are more likely to cause nuisance from smell than any other method of filtration'. The remedies appear to be limited to construction of the filters 'in an isolated site, or to subject the tank liquid to some deodorizing process before distribution on the filters'.

Crude sewage deposited on irrigable land and the over-sewaging of land surfaces will produce smell, especially if the land is dirty or not well cultivated. The remedies obviously are better preliminary treatment and cultivation of the surface soil, extension of the irrigable area, and longer rest periods.

[1] See the Public Health Act, 1875, as to extra-metropolitan districts. Within the Metropolis the county council are under an obligation to keep the Thames as free from sewage as practicable.

[2] *Sewage Purification and Disposal*, Kershaw, pp. 281–2.

Sludge is a notable cause of offence and every care is required in its disposal. For small installations deposit in trenches and covering with clean soil, as suggested on p. 400, is the most satisfactory solution.

Activated Sludge Purification Processes

Purification of sewage is effectible by artificial aeration, usually described as the 'sewage activation' or 'activated sludge' process, where mechanical power is available for working the plant.

Dr. Fowler, at the Manchester Sewage Works, found that the effect of activating sewage by blowing air through it for some weeks was to produce a completely oxidized, bright, supernatant liquid, and a deposit which was quite unlike ordinary sewage sludge. Repeated experiments on the fill-and-draw system, using and accumulating the then so-called 'activated' sludge, resulted in a gradual lowering of the time necessary to effect purification, until finally, when sufficient activated sludge had been collected in the system, complete oxidation took place in a few hours.

The process is entirely aerobic, and a claim is made that it avoids the putrefactive action set up by anaerobic organisms in sedimentation and septic tanks with the consequent production of an odorous liquid and a large quantity of foul-smelling sludge; is free from smells and flies; can be worked on a small area of land close to buildings; produces a fully-oxidized effluent not subject to secondary decomposition and meeting the standard of the Royal Commission on Sewage Disposal (p. 456) and a non-odorous sludge of manurial value; and is applicable to both trade waste and domestic sewage.

Activated sludge is essentially different from that produced in a septic tank, as it is inoffensive and possesses in the presence of atmospheric oxygen marked powers of purification. The quantity needed as a base for the rapid oxidation of the fresh or raw sewage brought into contact

for purification approximates to 25 per cent. of the tankage capacity.

Purification is apparently a threefold process, (*a*) coagulation of colloids or their absorption on the surface of the 'sludge', (*b*) a rapid oxidation of carbonaceous matter followed, if the process is carried to a finish, by (*c*) the formation of nitrates. The two former processes produce a stable liquid, but further aeration is usually desirable for the purpose of forming nitrates in the liquid, thus securing a highly purified and non-putrescible effluent.

From a million gallons of sewage about 42 tons of sludge are obtained. The latter contains large numbers of bacteria, 1 c.c. having been found to yield as many as 22 millions in addition to a varied protozoan fauna. The colour is dark brown, and an earthy but non-offensive odour is noticeable. It contains 97 to 99 per cent. of water, and owing to its extremely flocculent nature a thoroughly satisfactory means of drying so as to fit it for commercial use has not been found. Microscopical examination discloses its composition as an immense number of minute 'sausage skins' containing water and not easily broken up. If run into a lagoon—with preferably an ash bed—it can be air-dried and the moisture reduced to 75 to 85 per cent. in about four days, at which stage it loses its colloidal nature, becomes granular in appearance, odourless, and spadeable. 'Pressing' will further reduce the moisture content, and by artificial drying the moisture can be reduced to about 10 per cent. Kershaw states[1] that 'the two methods of dealing with this sludge which appear likely to be most successful are drying in thin layers on a specially constructed bed, and irrigation through pipes on land'.

The effluent from a satisfactory treatment is pure, stable, clear, and free from colloids, the last mentioned owing probably to the presence of a clotting enzyme in the activated sludge. It has a low saline ammonia content

[1] *Sewage Purification and Disposal*, Kershaw, p. 318.

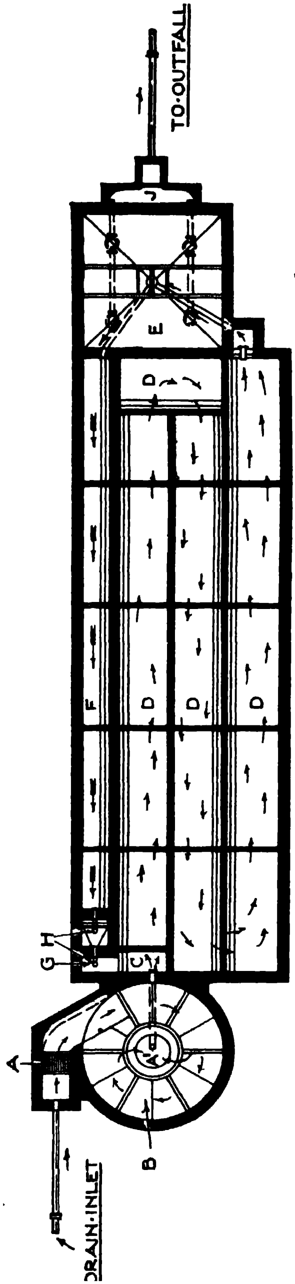

FIG. 299. Plan of typical activated sludge plant.

A. Coarse screen.

A¹. Grease-collecting chamber and fine screen.

B. Disintegration tank.

C. Mixing chamber.

D.D.D.D. Aeration channels.

E. Sludge settlement tank with 'Clifford' inlet.

F. Re-aeration channel.

G. Sludge return to mixing chamber.

H. Air lifts.

J. Final effluent channel.

and high nitrates, absorbs but little oxygen, and shows a bacteria reduction of about 98 per cent.

Of the systems of aeration employed, reference may be made to (1) blowing of compressed air into or through

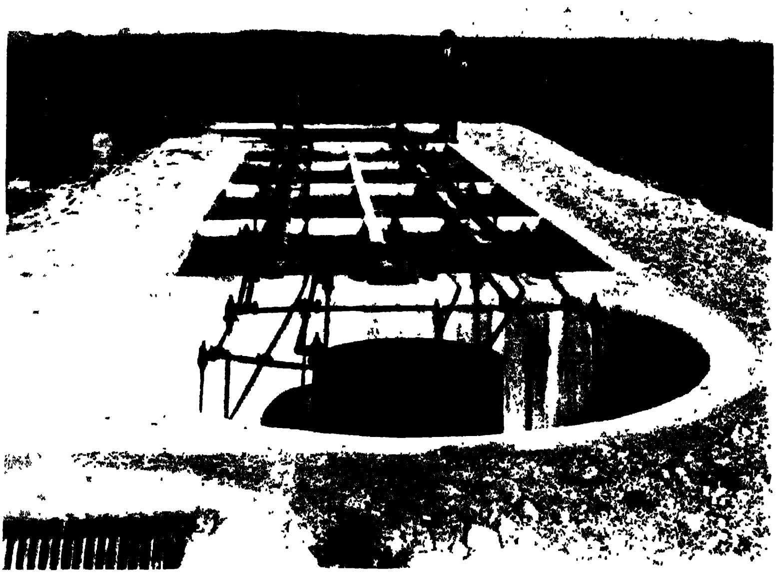

FIG. 300. View of activated sludge installation.

the sewage, (2) mechanical stirring or agitation of the surface, and (3) surface spraying. The principle of purification by activated sludge is common to all.

(1) *Compressed-air or 'air-blown' process.*—The purification process as carried out by Messrs. Activated Sludge, Ltd.,[1] is one of forced aeration in tanks after rough screening of the crude sewage and settling out of the detritus.

The lay-out of the system is shown by Figs. 299 and 300, the former being the plan of a typical plant and the latter a plant in operation.

[1] The Author is indebted to Messrs. Activated Sludge, Ltd., for the particulars here given and also for permission to reproduce Figs. 299 to 302.

The course of treatment is as follows: After separation of the grit the sewage passes through a coarse screen to a tank where the solid matters are broken into small particles presenting a large surface for subsequent treatment, the disintegration being effected by blowing through the sewage minute bubbles of air from porous diffusers in the bottom of the tank. Some aeration takes place in the disintegrating tank, but not to any appreciable extent, for the aerobic bacterial culture or activated sludge is not present. The sewage then flows into a grease-collecting chamber (from which the grease is removed periodically), from whence it is drawn off at the bottom and passed to a chamber, mixed with a percentage of previously re-aerated or re-activated sludge (15 to 30 per cent. according to the character of the effluent desired), aerated by a diffuser, and then passed into an aeration channel fitted with a series of diffusers causing a lively circulation, where the purification takes place. After purification the liquid is discharged to a settlement tank furnished with a 'Clifford' inlet (Fig. 303), which brings about quiescence of the liquid and deposition of the sludge.

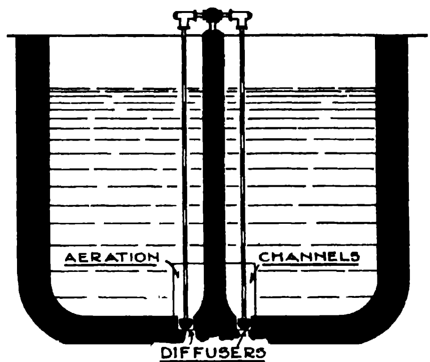

FIG. 301. Typical section of aeration channels, showing air diffusers and pipe connexions.

Fig. 301 gives a section through an aeration channel, and Fig. 302 illustrates surface circulation of sewage under treatment.

The purified effluent is run over weirs to the outfall and the sludge is returned to the re-aeration or re-activation channel, from which the surplus is drained or pumped out at intervals into a lagoon for air-drying or for special dehydrating treatment.

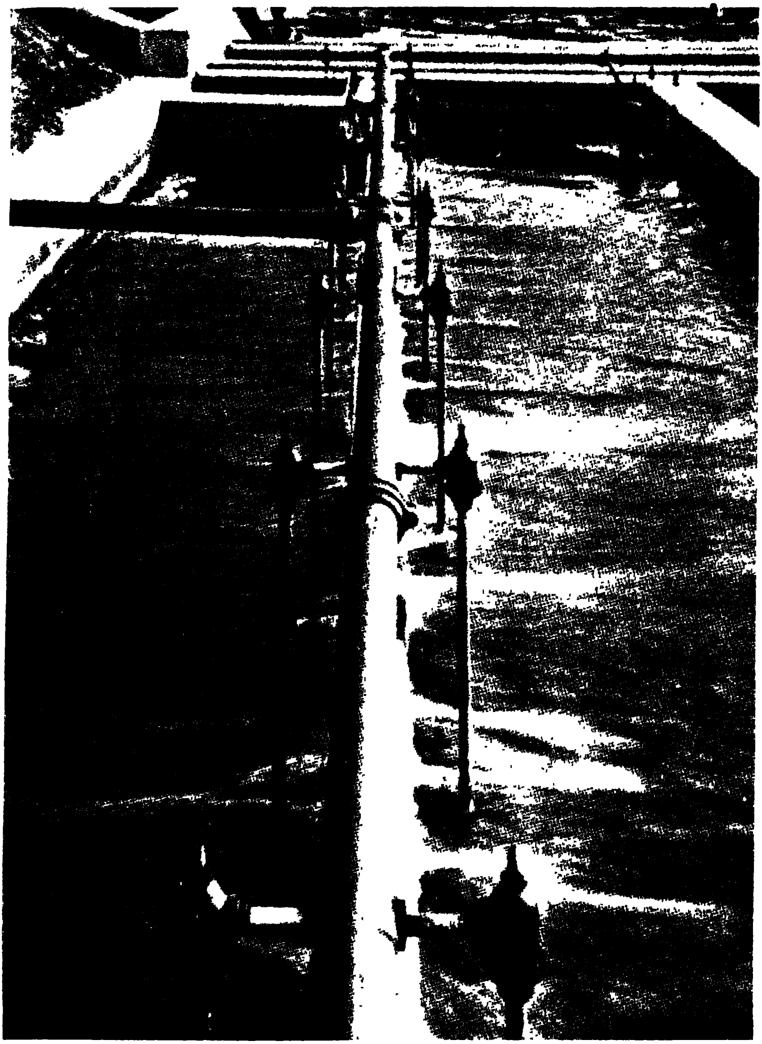

FIG. 302. View of activated sludge aeration channels, showing circulation of sewage.

The period needed for aeration varies with the nature of the sewage. The time usually required for a medium sewage is 6 to 8 hours; a weak sewage may be aerated in 2 hours, while a strong sewage may take 24 hours.

Tankage at the rate of 3 to 4 cu. ft. per head of population is required.

A supply of compressed air is essential. For domestic sewage this may be put at 1 to 2 cu. ft. per sq. ft. of diffuser-tank area at a pressure of not less than $\frac{1}{4}$ lb. per sq. in. more than the pressure due to the liquid; 5 to 10 lb. per sq. in. being adequate. The compressed-air plant should be in duplicate.

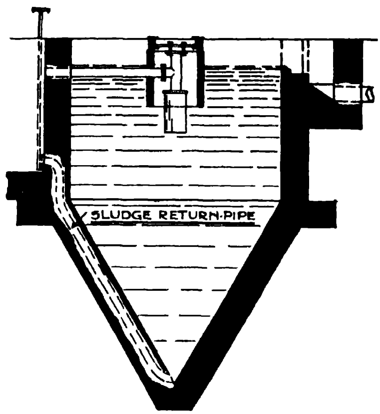

FIG. 303. Sludge settlement tank with patent 'Clifford' inlet.

(2) *The 'bio-aeration' process.*—This process of activated sludge purification was developed by Mr. Haworth of Sheffield. Instead of 'air-blowing', the sewage, after being screened and passed through a detritus chamber, is run into an aeration tank planned as a continuous channel, where it is mixed with activated sludge and mechanically agitated by paddle-wheels and moved continuously for a sufficient length of time (6 to 8 hours or more according to the flow and strength of the sewage with identical rates of in- and out-flow), the oxygen required for biological purification being absorbed from the atmosphere by the constantly changing surface of the flowing sewage.

The activated sludge retained for treatment purposes amounts to 25 to 30 per cent., any excess being removed as necessary.

From the aeration tank the mixture is passed into settling tanks where the liquid and sludge are separated, the former discharging to outfall and the latter to a land filter. Fig. 304 illustrates the general arrangement of settling tanks, aeration channels, &c.

(3) *'Simplex' surface aeration process.*—With this process

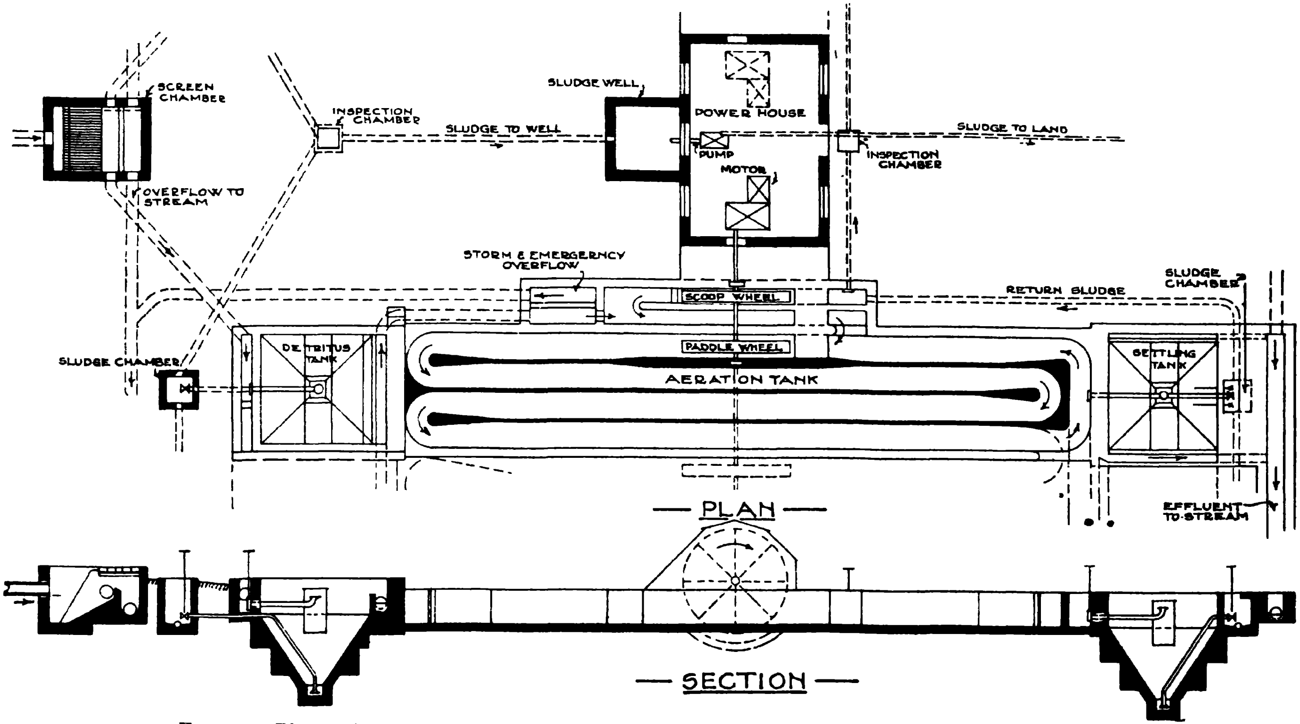

FIG. 304. Plan and section showing partial lay-out of sewage-disposal works ('Bio-aeration' system).

the sewage, after screening and sedimentation of the detritus, is passed into a tank containing 20 to 25 per cent. of activated sludge and having a central tube in the upper end of which is a power-driven rotating cone fitted with vanes. The sewage is circulated and re-circulated downwards in the tank and upwards through the tube by the working of the vanes, which throw out from the tube a thin film or 'wave' of sewage in a fashion inducing a circular movement so that it descends to the bottom of the tank, circulation being given to the tank content three times an hour. For aeration purposes oxygen is absorbed from the air by the sewage 'wave' and carried down into the mass.

The period of treatment varies with the nature of the sewage; usually eight hours is found to be sufficient. The unwanted sludge is drawn off periodically and disposed of in sludge-beds or filters.

Figs. 305, 306, and 307, respectively, illustrate an experimental tank, a typical lay-out of plant for dealing with 100,000 gallons of sewage per day, and an enlarged plan and section of tanks.

Standard of Purification for Effluents

The degree of purification is not easy to establish. No legislative standard is laid down as to what constitutes a polluting liquid from a factory or manufacturing process. True, the prohibition in the Rivers Pollution Prevention Act against allowing *sewage matter* to discharge into streams is absolute, but this expression is not defined in the Act nor in the Public Health Acts. Apparently no dis-distinction is to be drawn between trifling and serious pollution, nor regard had to the initial condition of the stream receiving the discharge; and hence an effluent may be expected to attain the purity standard of potable water, notwithstanding that it may discharge into a sewage-polluted stream.

The nearest approach to guidance is the general

standard for effluents discharging into non-tidal waters recommended in the Report of the Royal Commission on Sewage Disposal,[1] viz. that the suspended matters must

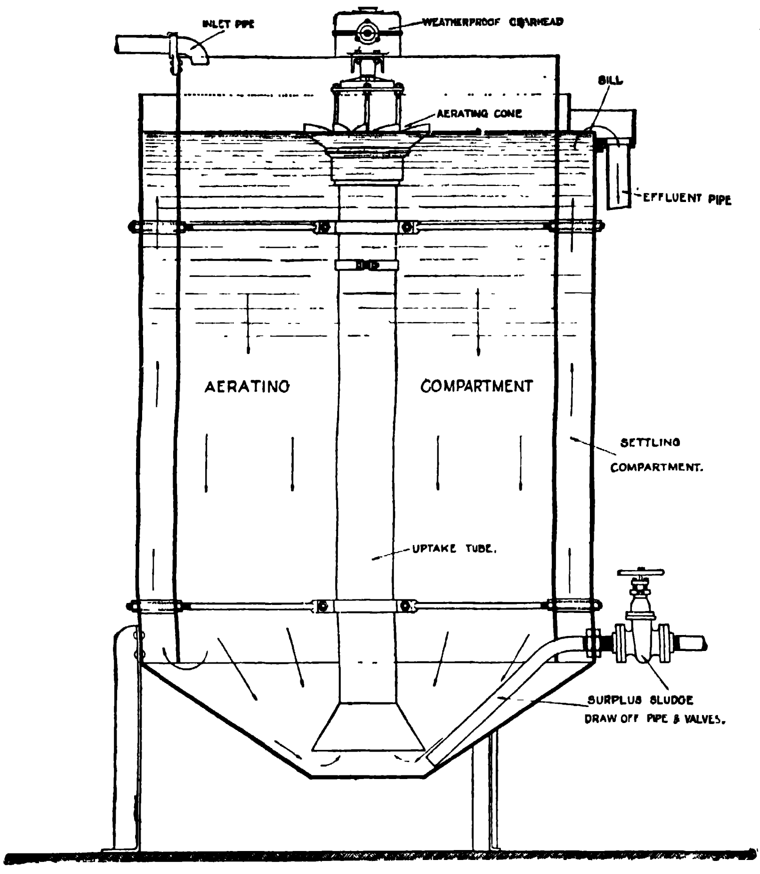

FIG. 305. Section of 'Simplex' tank.

not exceed three parts per 100,000, and with its suspended matters included the effluent must not take up at 65° F. more than two parts of dissolved oxygen in five days; a standard, however, subject to raising or lowering according to whether the stream into which the effluent is discharged respectively allows for 'very low' or 'very great'

[1] *Eighth Report (1912), p. 17.*

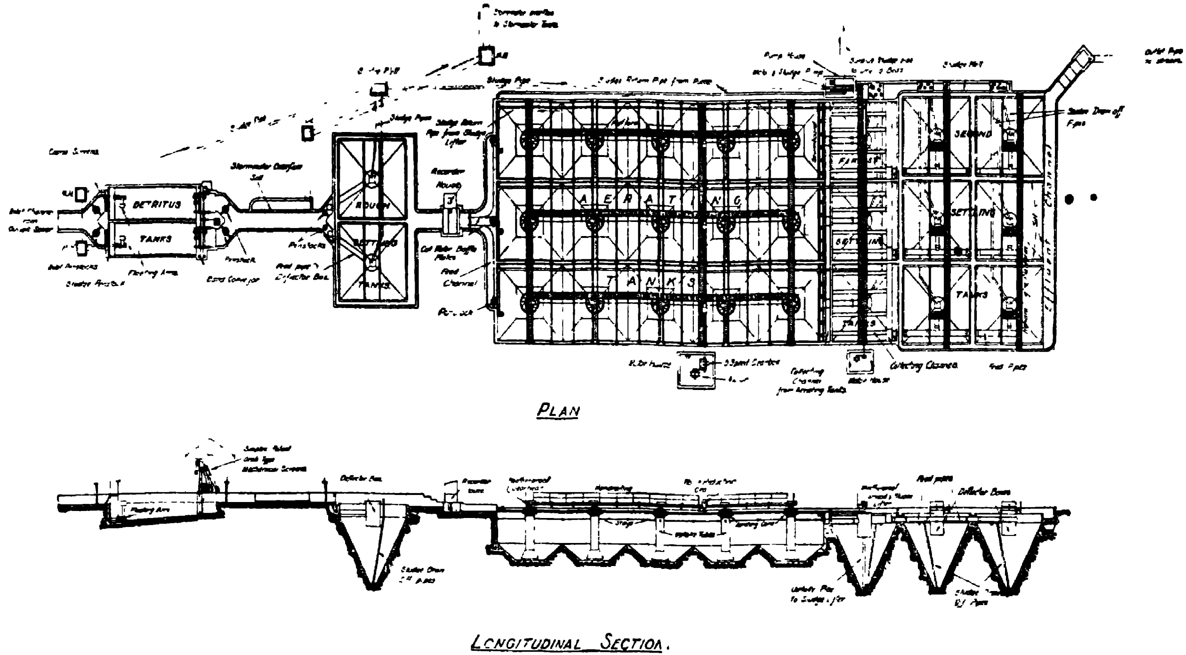

FIG. 306. Typical lay-out of 'Simplex' plant for treating 100,000 gall. (D.W.F.) of sewage.

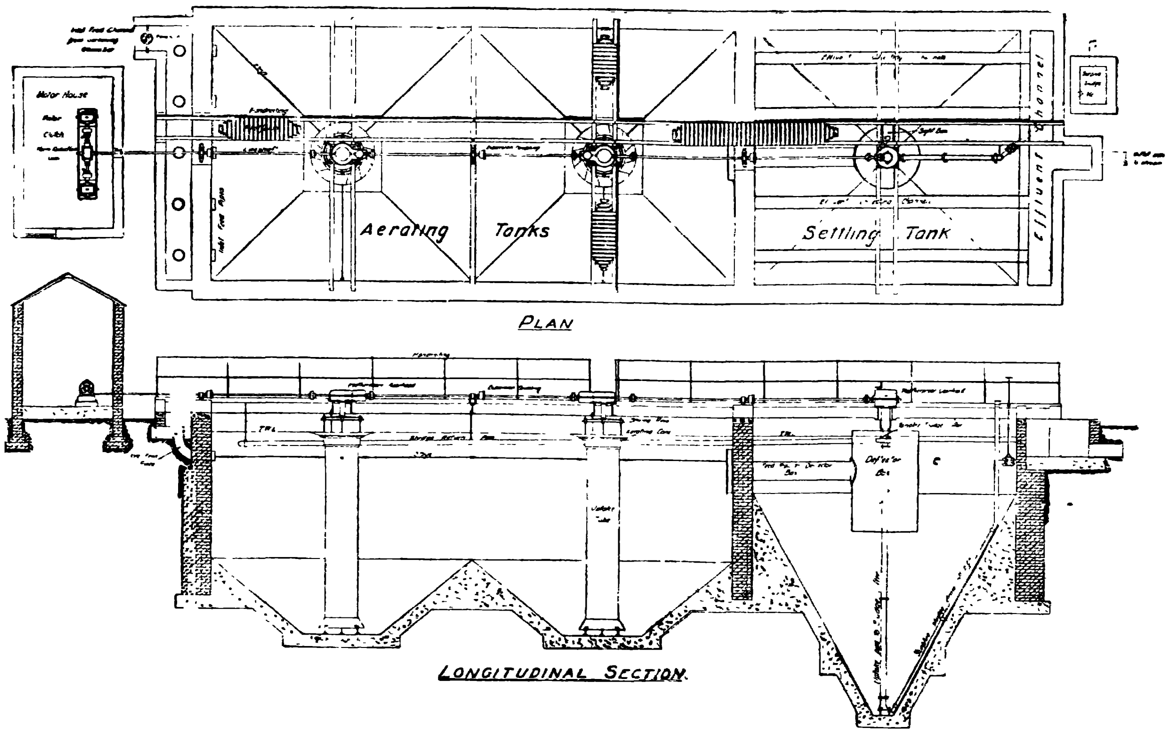

FIG. 307. Enlarged plan and section of 'Simplex' settling and aerating tanks.

dilution. Other conditions are that the effluent must not contain pathogenic organisms, and 'whether sterile or non-sterile must be relatively free from all substances susceptible to the action of putrefactive bacteria'.[1]

Of the processes dealt with, land treatment produces the best effluent. For the effluent from contact beds and percolating filters final treatment through fine-graded filters or land is always desirable prior to discharge into a stream. To quote Sir Alexander Houston, K.B.E.: 'Both bacteria-bed and land processes can yield effluents seemingly non-putrescible, but not to be thought of as safe for drinking-streams.'[2]

Sewage Raising

In the planning of installations it is a great advantage if the surface contour of the site is such that it provides sufficient fall to permit of the sewage gravitating from the place of origin, through the subjective process or processes, to the outfall or place of final disposal. This ideal state not infrequently is unattainable, with the consequence that the sewage must be raised (at any one or the several points) on reaching the treatment works, for the process or processes, and, after treatment, for discharge by gravitation to the outfall.

Where raising is needed the appliances should be automatic in action. The type largely favoured is a lift or ejector worked by compressed air through the agency of the sewage itself or a water-supply with a manipulative head. The former is illustrated by Fig. 258. Where electrical or other power is available, a compressed-air ejector (Fig. 259) can be used, or a motor-driven pump with an automatic control float.

Sludge raising may similarly be provided for by ejector or pump. In the case of very small installations it may be sufficient to provide a hand-worked pump as shown by Fig. 264.

[1] *Second Report of the Royal Commission on Sewage Disposal* (1902), p. 27.

[2] Ibid., p. 29.

Choice of Purification and Disposal Method

A decision as to the best applicable method depends upon the relative importance of many factors, including: position and contour of site; area; description of soil; purification substances available; position and character of outfall; nature and volume of sewage; the working of power-driven appliances; and supervision and control. Without adequate data on these points a dictum of any value is impossible.

For small and purely domestic installations it may, however, be submitted that the method chosen should be simple in character and design, automatic in action, as nearly fool-proof as practicable, and controllable with the minimum of expert attention. These conditions may be met by simple land treatment combined with a preliminary settling-tank and dosing siphon, and by a percolating filter combined with septic and humus tanks.

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